Philosophy vol 4.

A
DISSERTATION
UPON THE
PHÆNOMENA
OF THE
HARVEST MOON.
ALSO, THE
DESCRIPTION and USE
OF A NEW
FOUR-WHEEL'D ORRERY,
AND AN
ESSAY
UPON THE
MOON's turning round her own AXIS.

By *JAMES FERGUSON.*

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PREFACE.

THE Deſign of the following Work is,

I. *To explain the Cauſe, as well as the Appearance of the Harveſt Moon: I mean, the Reaſon why, for ſeveral Nights together about the Time of her being Full, ſhe riſes ſo near to the Time of Sun ſetting, in Harveſt, and not at any other Time of the Year: A Thing which many People remark, without being able to aſſign any natural Cauſe for it; and others look upon it as nothing but a vulgar Error; denying it, either for want of due Conſideration, or of proper Opportunities to obſerve it. And therefore, I have endeavoured to ſet it in ſo clear a Light, that any one who is but a little acquainted with the Uſe of a common Globe, may underſtand its Cauſe, and all the Varieties of its Appearances.*

II. *To deſcribe a ſimple Orrery, wherein the Motions of the Sun, Earth, and Moon, are repreſented; becauſe more can be learned in two Hours by ſeeing theſe Things performed in a Machine, than by many Days reading in Books, where theſe Motions are only deſcribed by Plane Figures. Yet, in the Way that Orreries are commonly made, the vaſt Number of Wheels they contain, and the Ornaments about them, make them ſo very hard to purchaſe, that many, who would be glad of the Inſtruction, cannot afford the great Expence of buying; and others perhaps never have the Opportunity of ſeeing one, in their whole Lives. And therefore, I have contrived a very ſimple Orrery; having no more than four Wheels to perform its different Motions; and ſuch a Machine can be eaſily purchaſed, and has the Globes repreſenting the Sun, Moon, and Earth, much bigger than they can be in large Orreries (where the Planets are all crouded together) and conſequently, the Motions of thoſe that moſt nearly concern us, with the Places on our Earth, ſo much the better defined; and their Uſes more amply ſhewn: As will appear by reading the Deſcription of this Orrery, and comparing it with the Deſcription of any other that may perhaps contain two hundred Wheels.*

III. *To remove a Doubt that I thought had only been made by few, but now I find ſeveral have, concerning the Moon's turning round her own Axis; it being difficult for ſome to underſtand, how a Body that circulates round about another, and ſtill keeps one Side thereto, can turn round an Axis within itſelf; and by others, poſitively denied that it can. I have therefore ſtated the moſt weighty Objections that I have heard, without Prejudice; and anſwered them in the beſt Manner that I could, with Impartiality; intirely for the*

Sake of Truth, and not of Argument; reſigning the Examination of my Proofs, to the Judgment and Criticiſm of thoſe who are proper Judges. In this Part, I have deſcribed a very ſimple Machine, which I contrived on Purpoſe, to ſhew all the various Phænomena of a Body's turning or not turning round its own Axis, with, or without a progreſſive Motion, when viewed from another Body either at Reſt or in Motion. This Machine has but three Wheels, and yet ſhews the Paralleliſm of the Earth's inclined Axis through its whole annual Courſe, from which ariſe the beautiful Variety of the Seaſons, and the different Lengths of Days and Nights. It likewiſe ſhews the periodical and ſynodical Revolution of the Moon, and all her different Phaſes as ſhe goes round the Earth. Here is a ſort of Orrery, ſo ſimple, that any ordinary Mechanic may make it from the Figure and Deſcription, in a very little Time, and at a very ſmall Expence.

Laſt Year, I publiſhed a Deſcription of an Orrery that I made; ſhewing the Motions of the Sun, Mercury, Venus, *Earth, and Moon: Concerning which Deſcription, I do here make two Apologies; the one for an Error of my own, concerning* Venus, *where I have ſaid, that her Days and Nights are not always equally long at her Equator; which I have found ſince, upon further Conſiderations, to be a Miſtake, whereto I was naturally led, by the Sun's being on ſome Days twice as high above the Horizon at Noon, as he is below it on the preceding or ſucceeding Night; and* vice verſa *at other Times; on account of his quick and great Declination. But I ſuppoſe there are many who will think it could not be otherwiſe; the Length of Day and Night being uſually meaſured by the diurnal and nocturnal Arches. But for a better Deſcription of that*

Planet's Motion, as ſhewn in my Orrery; ſee the Philoſophical Tranſactions, N°. 479, *for* March *and* April, A. D. 1746. *The other Apology is not for my own Fault, but for the Printer's, who performed his Part ſo ill, that it muſt be a Pain to read it. I hope the following Papers will give more Satisfaction on that Account; and if they pleaſe thoſe who are proper Judges of what they contain, and be any Way inſtructive to others, my End in compoſing them will be fully anſwered.*

A DISSERTATION UPON THE PHÆNOMENA OF THE HARVEST MOON.

Wherein the Harveſt Moon differs from other Moons.

IT is commonly obſerved, that the Moon every Night or Day riſes about 48 Minutes later than on the preceding; except in Harveſt, when about the Full, ſhe riſes for three or more Nights ſucceſſively within the Compaſs of an Hour. And as no other Full Moon does ſo in the whole Year, the well-meaning Huſbandman piouſly aſcribes it to the Goodneſs of God; who, he ſays, has ordered it ſo, to give him an immediate Supply of Light after Sun-ſetting, that he may have the more Time for gathering in the Fruits of the Earth. And he is ſo far in the right, as our Creator has made a few natural Cauſes produce various Effects, which are won-

None at the Equator.

Very remarkable at the Polar Circles.

derful in themſelves, and highly beneficial to his Creatures. One Inſtance of this is the Harveſt Moon; for at the Equator, where there is no Winter, and conſequently, no Danger of having the Fruits of the Earth ſpoiled in Harveſt by any ſudden Change of the Weather, the Moon riſes nearly with the ſame Difference of Time throughout the whole Year; being much about 50 Minutes later every Day or Night than on the preceding. But as Places are more remote from the Equator, the Weather changes to a greater Degree of Cold, after the autumnal Equinox: And as the Places are more remote, the nearer to the ſame Time for Nights together does the Full Moon next the autumnal Equinox riſe; until we come to the Polar Circles, or 66½ Degrees from the Equator, where ſhe will not differ above an Hour in her riſing for 15 Nights together, or from the firſt to the third Quarter; in which Time ſhe will differ almoſt 24 Hours in her ſetting through that Part of her Courſe.

The Reaſon of all this will plainly appear, by conſidering it in the following Manner.

A Reaſon for it.

The Earth's Axis, whereon it turns round every Day, is perpendicular to the Plane of the Equator, and inclined to the Plane of the Ecliptic: For which Reaſon, it is certain that in any given Latitude, all Parts of the Equator riſe in the Eaſt, and aſcend therefrom at the ſame Angle with the Horizon; conſequently, equal Parts of it will always riſe in equal Times. But it is not ſo with the Ecliptic; for, becauſe of its Obliquity, ſome Parts of it will riſe at much greater Angles with the Horizon than others: And, in equal Times, whenever this Angle is leſs, then will a greater Portion of the Ecliptic riſe in the ſame Time; and *vice verſa*.

In the Northern Latitudes, none of the Signs riſe and aſcend from the Horizon with ſo ſmall an Angle, nor ſet with ſuch a great one, as *Aries* does; to which *Libra* is quite the reverſe. Therefore, in an Hour or ſo, a greater Quantity of the Ecliptic will riſe in, or about *Aries*, than in any other Sign, and a leſſer Quantity in, or about *Libra*.

As the Places are gradually more and more diſtant from the Equator, the Angle which the Ecliptic makes with the Horizon, at the riſing of *Aries* in the Eaſt, gradually diminiſhes, till we come to the Polar Circles, where there is no eaſtern Angle at all; becauſe one half of the Ecliptic there, riſes all at once. And this makes it plain, that if the Sun would ſtand ſtill for 15 natural Days together at the Beginning of *Libra*, we would have 15 Days juſt equal to their reſpective Nights in Length, each being 12 Hours. And if the Moon was juſt one Quarter old on the firſt of theſe Days, ſhe would then be at the Beginning of *Capricorn*; and in going from thence to the Beginning of *Cancer*, ſhe would for fifteen Evenings together, riſe at the ſame Time, namely, juſt when the Sun was ſetting; becauſe for 15 Days and Nights ſhe would be in that Semi-circle of the Ecliptic which riſes all at that Hour. Her firſt Appearance or Riſing would be on the South Point of the Horizon; in which juſt one half of her Diſk would appear, and ſhe would ſet immediately. The next Night ſhe would riſe at the ſame Time, but ſomewhat more than a Point of the Compaſs toward the Eaſt, and would ſet as far from the South toward the Weſt, but would be an Hour and 36 Minutes later in Time, though almoſt at the ſame Amplitude. Thus, in 15 Nights, ſhe would vary her riſing Amplitude through all the eaſtern Semi-circle of the Horizon, but the Time would be ſtill the ſame, and her ſetting Amplitude through all the weſtern Semi-circle of the Horizon, but the Time would differ juſt 24 Hours. For, the Semi-circle which riſes all at once on the one Side, is 24 Hours of ſetting upon the other; and this Quantity of Time divided by 15 Days, allows to every Day one Hour and 36 Minutes, or the Difference of Time wherewith the Moon would ſet from her firſt to her third Quarter every Day.

But, becauſe in 15 Days, the Sun moves almoſt 15 Degrees, and conſequently, in a whole Lunation almoſt a whole Sign, it is plain that in 15 Days the Moon will move through almoſt 15 Degrees more than a Semicircle of the Ecliptic (as ſhe moves through the whole of it in $27\frac{1}{3}$ Days) which will make about an Hour's Difference in her riſing and as much in her ſetting; that is, ſhe will be one Hour later of riſing and 23 of ſetting in the above Time. Through the other 15 Days of her Courſe, or from the third Quarter of that Lunation to the firſt Quarter of the next, ſhe will differ but one Hour in her ſetting, and 23 in her riſing; being the moſt of that Time in the other Semi-circle of the Ecliptic, which always ſets when the former riſes.

Remark.

From this it follows, that the nearer to the ſame Time the Moon riſes for few or many Nights together, the greater is the Difference in Time of her ſetting through that Part of her Courſe; and *vice verſa*.

Here we are ſuppoſed to conſider the Moon as moving only in the Ecliptic, without regarding at preſent what happens on Account of her moving in an Orbit inclined thereto; becauſe it gives a more general and eaſy Idea: Which being underſtood, I ſhall ſoon proceed to deſcribe the Harveſt-Part of her Phænomena, as ſhe moves round the Earth in her own Orb, which is $5\frac{1}{3}$ Degrees inclined to the Plane of the Ecliptic, wherein the Sun appears to move almoſt a Degree every Day, and ſo of Courſe to go round the ſame once every Year.

How the Harveſt Moon riſes and ſets in general at *London*.

On the Parallel of *London*, the Ecliptic, where it interſects the Equinoctial in *Aries*, riſes always in the Eaſt at an Angle of 15 Degrees with the Horizon, and ſets at an Angle of 62 Degrees therewith in the Weſt. This may be ſhewn by a common Globe; and allowing the Moon to go through $13\frac{1}{6}$ Degrees always in 24 Hours, as much of the Ecliptic will riſe about *Aries* in an Hour, as the Moon can go through in almoſt three Days; and conſequently, an Hour divided among three Days is 20 Minutes to each; and only ſo much later will the Moon riſe in each of theſe Days in the Evening. But ſo much of the Ecliptic will be at leaſt four Hours in ſetting; which being divided among the above three Days, allows an Hour and 20 Minutes to each; and ſo much later will the Moon be at her ſetting in the Morning of each of theſe Days. All the Degrees of *Piſces* and *Aries* riſe and ſet almoſt at the ſame Angle as the Beginning of *Aries* does; and therefore, while the Moon is going through theſe two Signs, ſhe will have much the ſame Difference in her riſing and ſetting, as abovementioned, or for five Days.

Some Part of every Moon riſes and ſets like the Full Moon in Harveſt.

Becauſe the Moon goes through all the Signs and Degrees of the Ecliptic in 27 Days and 8 Hours, it is certain, that in ſome Part of every Lunation, ſhe will riſe and ſet in *Aries* with the ſame Difference of Time as above ſpecified, for the like Number of Days: But this is pretty much out of the Way of common Obſervation, becauſe the Moon is not full in *Aries* at any Time except in Harveſt; and at no other Time does *Aries* riſe when the Sun is about ſetting. For, in Winter, it riſes about Mid-day, when the Moon in it is but one Quarter old: In Spring, it riſes with the Sun; and then the Moon cannot be in it, but about her Conjunction or Change: In Summer, it riſes about Mid-night, with the Moon in her third Quarter: And ſo, in Harveſt, *Aries* riſes about Sun ſetting, with the Moon Full, or at her Oppoſition to the Sun in it.

As the autumnal Full Moon riſes and ſets in *Aries*, ſo the vernal Full Moon riſes and ſets in *Libra*: And therefore, ſince *Libra* riſes at as great an Angle with the Horizon in the Eaſt, as *Aries* ſets with in the Weſt, and ſets with as ſmall an Angle in the Weſt, as *Aries* riſes with, in the Eaſt, it is plain, that the vernal Full Moon will ſet with as little Difference of Time as the autumnal Full Moon riſes, and will differ as much in her riſing, as the other does in her ſetting.

The particular *Phænomena* conſidered.

And thus, having conſidered in general, how the Harveſt Moon would riſe and ſet if her Orbit lay in the Plane of the Ecliptic, which it does not; proceed we now to deſcribe it as it really is: And we will ſoon find, that the Moon's Progreſs being in an Orbit inclined $5\frac{1}{3}$ Degrees to the Ecliptic, cutting it in two diametrically oppoſite Points called the Nodes, will affect both her riſing and ſetting in a very remarkable Manner. And here let it ſuffice to ſhew theſe Affections on the Parallel of *London*, and the Arctic Circle, in different Poſitions of the Moon's Orbit, ſuppoſing the Days of her Age to be the ſame in theſe different Poſitions.

Firſt then, at *London*, let us ſuppoſe the Moon to be full in her aſcending Node, at the autumnal Equinox; and

How it really appears at *London.*

and ſhe will riſe due Eaſt in the Beginning of *Aries*, where that Part of her Orbit makes but an Angle of 9⅔ Degrees with the Horizon; which is 5⅓ Degrees leſs than the Ecliptic does. This is the leaſt Angle wherewith it can riſe to any Place on the Parallel of *London*; and conſequently will occaſion the leaſt Difference that can be in the Moon's riſing, which gives the moſt advantageous Harveſt Moon of any. For, as much of the Ecliptic will riſe about *Aries* in an Hour, as the Moon can go through in four Days; and therefore, ſhe will not be above 15 Minutes later in riſing every Evening for a whole Week, or ſo. But, as *Aries* in the Moon's Orbit will ſet in the Weſt at an Angle of 67⅓ Degrees with the Horizon, it is plain, that although the Moon will not differ much above an Hour and half in her riſing for ſix Nights together, ſhe will in that Time differ 7 Hours and almoſt a quarter in her ſetting; or an Hour and about 12 Minutes every Morning.

Secondly, let us ſuppoſe the Moon to be Full in her deſcending Node, at the autumnal Equinox; and then ſhe will riſe due Eaſt in the Beginning of *Aries*, where her Orbit makes an Angle of 20⅓ Degrees with the Horizon; which is ſomewhat more than double the Angle ſhe had (as above) in her aſcending Node, when it was in that Sign. And therefore, ſhe will be at leaſt half an Hour later of riſing every Night for a Week than on the Night before; becauſe there cannot riſe more than 27 Degrees of her Orbit about *Aries* in an Hour; which is ſcarce one Degree more than ſhe goes through in two Days. And this is the leaſt advantageous Harveſt Moon that can happen, though it is ſtill better than if ſhe ſhould be 48 or 50 Minutes later every Night in that Time, as ſhe commonly is at other Times of the Year. Here, the Difference of the Moon's ſetting for ſix Mornings, is leſs than in the preceding Caſe; for it is but an Hour and about 6 Minutes later every Morning.

If the Harveſt Moon be full in *Aries* as above, and be either in her greateſt North or South Latitude, her riſing then will have much the ſame Difference as if ſhe did really move in the Plane of the Ecliptic. But in her North Latitude, where it is greateſt, ſhe will riſe al-

moſt

oſt half an Hour before Sun-ſetting; and in her greateſt outh Latitude, ſhe will not riſe till almoſt half an Hour after the Sun ſets.

To bring theſe Things at once in View, I ſhall here give

A Table, ſhewing all the Varieties of the Moon's riſing and ſetting, from the 12th Day of her Age to the 18th Day thereof, ſuppoſing her to be Full at the autumnal Equinox; and then either in her North Node, higheſt North Latitude, South Node, or loweſt South Latitude. M *ſignifies Morning,* A *Afternoon.*

Moon's Age.	Full in her North Node.		In her greateſt North Latitude.		Full in her South Node.		In her greateſt South Latitude.	
	Riſes at H. M.	Sets at H. M.	Riſes at H. M.	Sets at H. M.	Riſes at H. M.	Sets at H. M.	Riſes at H. M.	Sets at H. M.
12	5 A 15	3 M 20	4 A 30	3 M 15	4 A 32	3 M 40	5 M 16	3 M 0
13	5 32	4 25	4 50	4 45	5 15	4 20	6 0	4 15
14	5 48	5 30	5 15	6 0	5 45	5 40	6 20	5 28
15	6 5	7 0	5 42	7 20	6 15	6 56	6 45	6 32
16	6 20	8 15	6 2	8 35	6 46	8 0	7 8	7 45
17	6 36	9 12	6 26	9 45	7 18	9 15	7 30	9 15
18	6 54	10 30	7 0	10 40	8 9	10 20	7 52	10 0
Dif.	1 39	7 10	2 30	7 25	3 28	6 40	2 36	7 0

It may perhaps be aſked, why does not the Table ſhew the Moon to riſe at the ſame Time in both Nodes on the 15th Day of her Age, ſhe being Full in each of them, and conſequently muſt at that Time be in the Plane of the Ecliptic? I anſwer, that ſhe is Full in 14¾ Days; and ſo in either Caſe ſhe is a little paſt the Node on the 15th Day, being a little above it in one, and below it in the other, which occaſions the Difference.

At the Polar Circles, one half of the Moon's Orbit will be below the Ecliptic, and the other half above it, when one half of it is juſt riſing on the eaſtern Side, and the other half ſetting on the weſtern Side, of the Horizon.

Phænomena of the Harveſt Moon at the Polar Circles.

Horizon. Therefore, when the North Node is in the Beginning of *Aries*, ſome Part of the Moon's Orbit, where the Latitude thereof is South, will not riſe; and while the Moon is going through that Part, ſhe will keep below the Horizon four Days and Nights completely without riſing: And when ſhe is in the oppoſite Part of her Orbit, which being of northern Latitude, ſets not, ſhe will be as many Days and Nights above the Horizon without ſetting. But when the Nodes have changed their Places ſo, as the South Node comes to the Beginning of *Aries*, every Degree of the Moon's Orbit will then riſe and ſet, and therefore, the Moon will then riſe and ſet, every Day of her Age.

How it is varied by the different Poſitions of he Nodes.

When the North Node is in the Beginning of *Cancer*, the Moon will differ but one Hour in her riſing from the 9th to the 24th Day of her Age, and 23 Hours in her ſetting for that Time: The riſing Difference being all in the laſt two of theſe Days; for from the 9th to the 22d Day, ſhe will conſtantly riſe at the ſame Hour; but, in that Time, her Amplitude will have changed from the South Point of the Horizon 160 Degrees northward, on the eaſtern Semi-circle thereof.

When the North Node is in the Beginning of *Capricorn*, the Moon from the 7th to the 22d Day of her Age will vary her riſing Amplitude 180 Degrees, or from the South to the North Point of the Horizon on the eaſtern Side thereof; but ſhe will ſtill riſe at, or very near the ſame Hour during that Time, namely, at ſix in the Evening; except only that about the 13th, 14th, 15th and 16th Days, ſhe will riſe about a Quarter of an Hour ſooner. And from the 7th to the 22d Day, ſhe will vary her Amplitude quite through the weſtern Semicircle of the Horizon, and differ 24 Hours in the Time of her ſetting.

In both theſe Caſes, the Moon during the other 15 Days, or from the third Quarter of that Lunation to the firſt Quarter of the next, will ſet with as little Difference of Time as ſhe roſe for the abovementioned 15 Days; and will riſe with as much, as ſhe ſet in that Time.

When the North Node is in the Beginning of *Aries* at the autumnal Full Moon, ſhe will riſe every Night ſooner than on the preceding, from the 10th to the 19th Day of her Age: But if the North Node be in the Beginning of *Capricorn*, ſhe will riſe later every Night than on the preceding, during the whole autumnal Lunation.

Becauſe the Phænomena are very curious, on Account of their being ſo variouſly affected by the Moon's different Latitudes, I ſhall here give a Table, ſhewing her riſing, ſetting and ſouthing, with her Amplitudes and Meridian Altitude, every Day for a whole Lunation, at the Arctic Circle; ſuppoſing her to be full one Year in the aſcending, and another Year in the deſcending Node.

A Table ſhewing the Moon's riſing, ſouthing,

Moon's Age.	Moon's riſing.				Amplitude at riſing.				Comes to the Meridian.			
	North Node.		South Node.		North Node.		South Node		North Node.		South Node.	
	H.	M.	H.	M.	Deg.	M.	Deg.	M.	H.	M.	H.	M.
1	7M	0	7M	15	0	0	0	0	0 A	50	1 A	15
2	8	30	8	40	12 S	30	11 S	45	1	45	2	4
3	10	15	10	5	29	10	22	0	2	15	2	52
4	0 A	15	11	25	50	0	30	6	3	10	3	35
5	2	15	0 A	30	67	10	36	45	3	55	4	30
6	Always below the Horizon.		2	0	—		43	30	5	0	5	20
7			2	45	—		43	40	5	45	6	15
8			3	20	—		44	0	6	40	7	0
9			4	28	—		40	30	7	36	8	15
10	8	30	4	56	90	0	35	10	8	30	9	6
11	7	0	5	28	56	30	28	30	9	28	10	0
12	6	35	5	36	40	10	20	6	10	26	10	32
13	6	20	5	45	23	36	12	20	11	15	11	16
14	6	8	6	0	10	6	1	30	11	50	12	0
15	6	0	6	10	7 N	0	5 N	0	0M	28	1M	0
16	5	48	6	30	22	5	15	0	1	10	1	36
17	5	36	6	50	38	10	22	30	2	9	2	30
18	5	22	6	58	55	5	34	0	2	45	3	18
19	4	8	7	10	90	0	39	10	3	36	4	0
20	Always above the Horizon.		7	55	—		45	0	4	30	4	38
21			8	28	—		48	12	5	40	5	50
22			9	15	—		47	10	6	45	6	45
23			10	30	—		42	30	7	30	7	25
24	8	10	11	42	90	0	36	40	8	15	7	55
25	11	34	1M	0	52	10	30	0	9	12	9	0
26	1M	20	2	15	37	15	23	10	9	50	9	40
27	3	30	3	45	17	0	14	5	10	28	10	28
28	5	0	5	0	3	30	3	30	11	20	11	16
29	6	20	6	15	9 S	0	5 S	0	11	50	11	45
½	7	40	7	0	16	2	9	10	0 A	12	0 A	10

and ſetting, &c. at the Arctic Circle.

Moon's Age.	Altitude on the Meridian.				Moon's ſetting.				Amplitude at ſetting.			
	North Node.		South Node.		North Node.		South Node.		North Node.		South Node.	
	Deg.	M.	Deg.	M.	H.	M.	H.	M.	Deg.	M.	Deg.	M.
1	24	0	23	30	6A	45	7A	12	9S	0	7S	0
2	17	10	18	38	6	30	7	15	23	10	17	12
3	11	45	14	0	6	4	7	20	42	30	26	10
4	5	40	11	30	5	52	7	50	56	10	34	0
5	1	30	8	30	4	46	8	8	83	40	41	30
6	Under the Horizon.		7	0	Always below the Horizon.		8	45	—		45	0
7			6	0			9	38	—		46	30
8			6	30			10	30	—		45	10
9			7	48			11	36	—		42	25
10	0	0	10	0	10	40	0M	40	64	0	37	10
11	5	30	13	26	0M	38	2	8	48	40	28	30
12	11	0	16	30	2	45	3	15	31	10	19	40
13	16	4	19	45	4	8	4	45	18	6	10	12
14	21	30	23	40	5	30	6	0	4	30	2	6
15	26	34	27	0	7	6	7	15	10N	0	6N	0
16	32	10	30	2	9	0	8	35	26	30	15	30
17	38	30	33	30	11	0	10	0	43	5	25	10
18	44	0	36	5	0A	50	11	40	60	10	34	30
19	47	50	39	0	Always above the Horizon.		0A	28	—		40	0
20	50	20	40	48			1	48	—		45	30
21	52	0	41	45			2	54	—		48	36
22	52	20	41	40			3	23	—		46	0
23	50	0	40	0			4	5	—		40	6
24	47	0	38	40	7	0	4	30	70	12	35	10
25	42	10	35	30	6	25	4	42	47	10	27	15
26	35	46	32	0	5	45	5	15	25	40	20	0
27	31	0	29	30	5	30	5	20	10	20	8	30
28	25	4	25	0	5	28	5	25	4	10	2S	0
29	20	10	21	12	5	20	5	30	12S	0	10	6
1 2	15	5	19	30	5	10	5	40	23	0	15	10

In this Table, M ſignifies Morning, A Afternoon N North Amplitude, and S South Amplitude: Ea Letter belonging to the Figures to which it is ſet, and all in the ſame Column below it, until another Lett comes in the Way.

It may ſeem almoſt incredible that there ſhould ſuch a great Difference of the Moon's riſing, ſouthing and ſetting, but eſpecially of her Amplitude, if ſhe Full in her South Node, from what would be if had then been Full in her North Node, as is ſhewn this Table. But if we conſider how much of the Moon Orbit will riſe in a few Minutes, the great Difference o caſioned by its different Poſitions will not be ſo ſu priſing. I ſhall here give an Example from the Tabl by taking out the Numbers belonging to the tenth D of the Moon's Age; and ſhewing the Difference of h Phænomena on that Day, if Full in her North Nod from what it would be if ſhe was Full in her Sout Node, about the autumnal Equinox.

			riſes at		riſ. Amp. is		comes to Merid. at	
In her	N. Node	ſhe	8^h 30^m	her	90^d 0^m S	ſhe	8^h 30^m	Mon.
	S. Node		4 56		35 10 S		9 6	
The Difference is			3^h 34^m		54^d 50^m		0^h 36^m	

			Altitude is		ſets at		Amplit.
In her	N. Node	her	0^d 0^m	and	10^h 40^m A	with	64^d 0^m
	S. Node		10 0		0 40 M		37 10
The Difference is			10^d 0^m		2^h 0^m		26^d 50^m

What is here ſet down, is not from numerical Calcu lation; but from the mechanical Operation of a ſimpl four Wheel'd Orrery that I have lately made, and a now going to deſcribe.

TH

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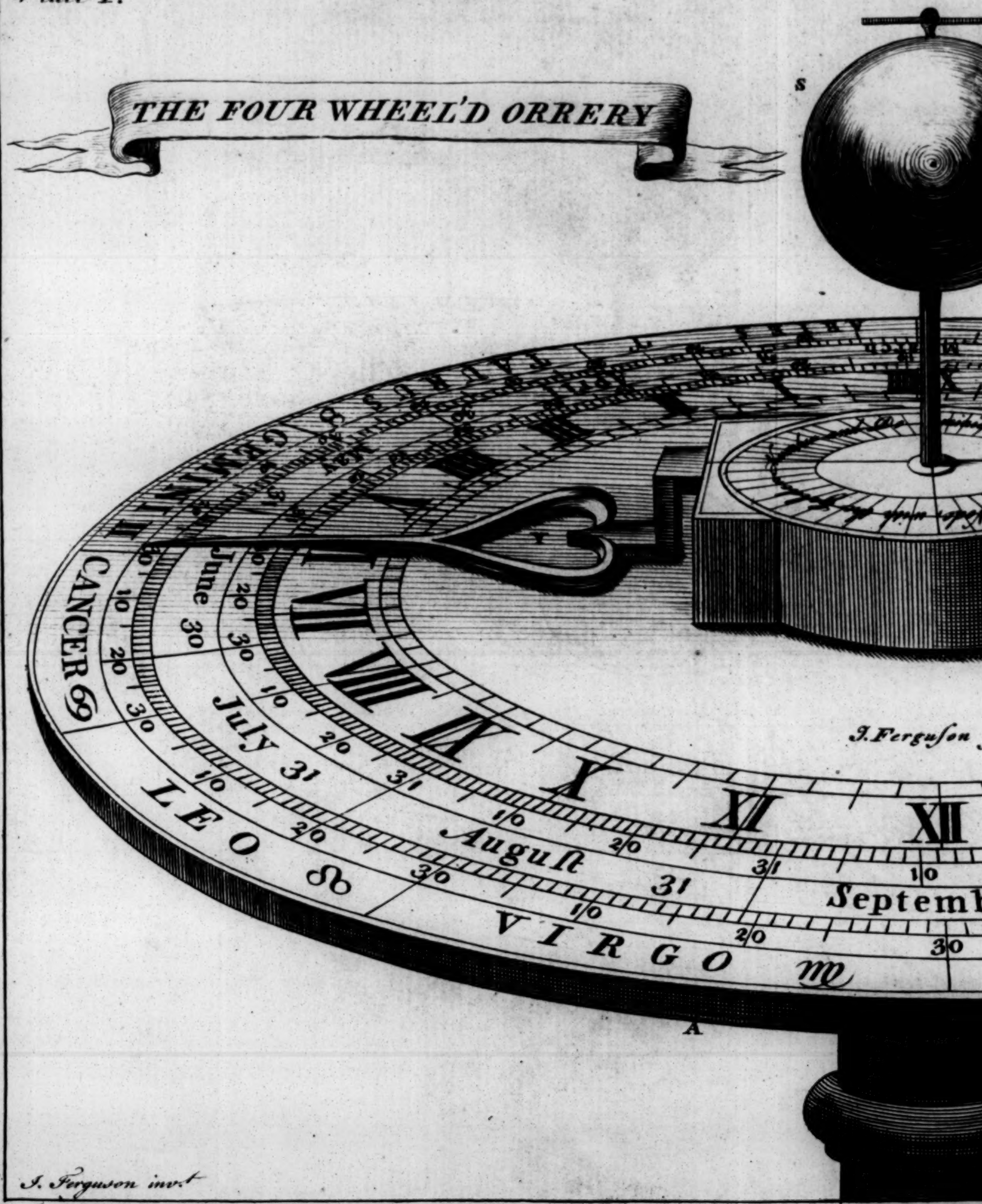
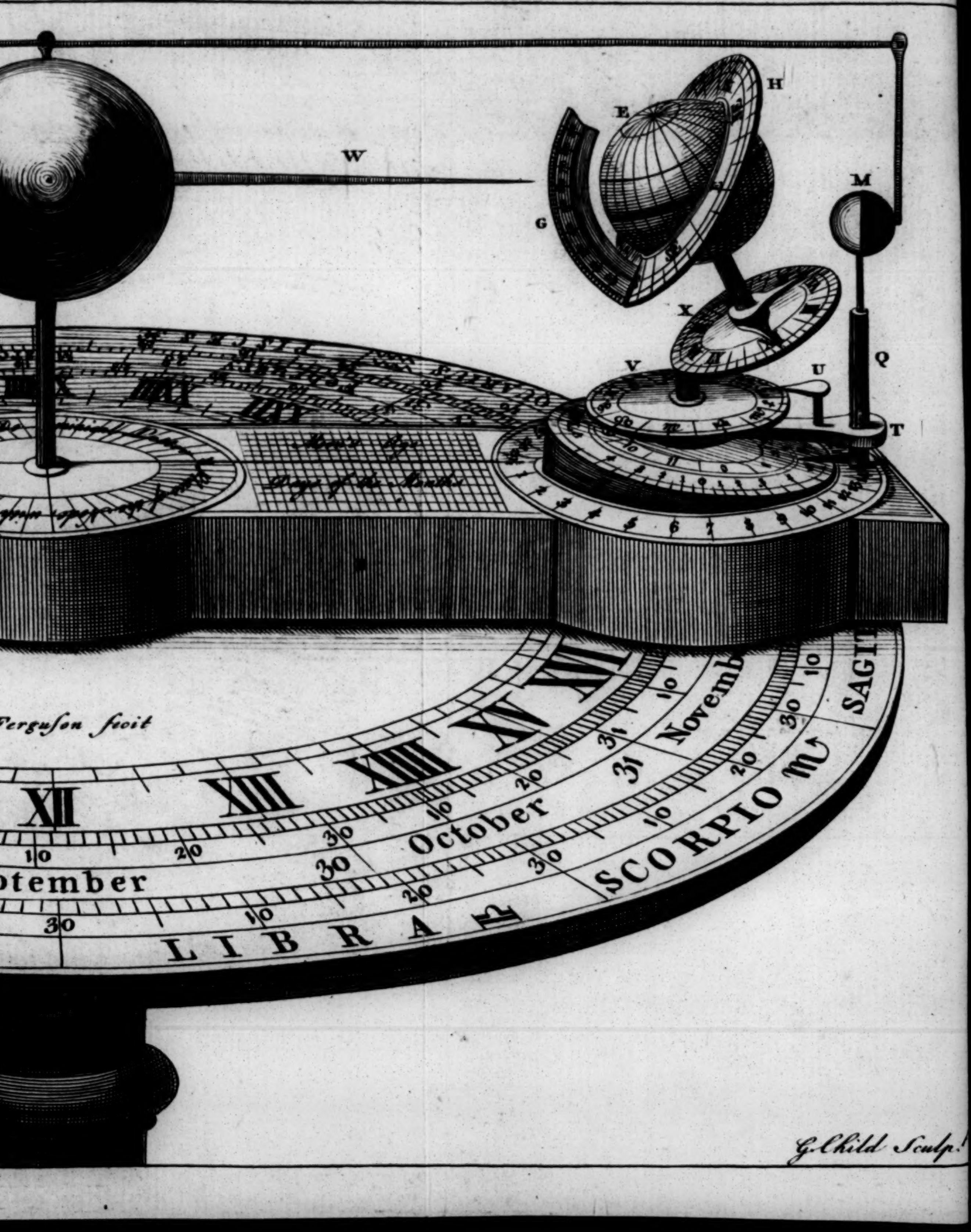
Plate I.

THE FOUR WHEEL'D ORRERY



J. Ferguson inv.t



Ferguson fecit

G. Child Sculp.

THE
DESCRIPTION and USE
OF AN
ORRERY,
HAVING
Only four Wheels, without either Pinion or Screw.

IN this Machine, S repreſents the Sun, E the Earth, and M the Moon. W, a Wire, is fixt in the Sun, and points towards the Earth's Center, but does not touch its Surface, becauſe of the graduated Arch G, which is fixt in the South Point of the Horizon H, and muſt go round with the Motion of the Earth, ſo as not to be hindered by the ſaid Wire. The Horizon has all the Points of the Compaſs drawn upon it, and likewiſe a graduated Circle ſhewing the Degrees of Amplitude both of the Sun and Moon. The graduated Arch has its Degrees number'd from the Horizon to the Zenith upon one Side, for ſhewing the Altitude of the Sun and Moon as they paſs over the Meridian; and on the other Side it is graduated from above the Equator to the Tropics and a little beyond them, for ſhewing the Declination of the Sun and Moon. The abovementioned Wire, Plate I.

which, in the following Parts of this Deſcription, I ſhall call a Solar Ray, ſhews the Sun's Amplitude at riſing and ſetting, every Day of the Year, as it cuts the Horizon on the eaſtern or weſtern Side thereof, while the Earth is turned round its Axis; and in paſſing over the graduated Arch, it ſhews both the Declination and Meridian Altitude of the Sun, which is different every Day, as the Amplitude likewiſe is; for the Earth's Axis is inclined $23\frac{1}{2}$ Degrees from a Line ſuppos'd to be drawn perpendicular to the Ecliptic; and as the Earth is carried round about the Sun, its Axis ſtill continues parallel to itſelf: That is, if in any Part of the Earth's annual Path, a Line be drawn parallel to its Axis, the ſaid Axis will always keep parallel to that Line.

Paralleliſm of the Earth's Axis.

Moon's inclined Orbit.

Her Nodes.

They go backward.

While the Moon goes round the Earth, ſhe riſes above and falls below the Plane of the Ecliptic, or annual Path of the Earth's Center, in her Orbit which is $5\frac{1}{3}$ Degrees inclined thereto. Conſequently, as one half of the Moon's Orbit is above the Ecliptic and the other half below it, her Orbit will cut the Ecliptic in two Points diametrically oppoſite to one another, and theſe Points are called *the Moon's Nodes*. They are marked upon the inclined Plane P, to which Plane the Moon always keeps parallel, becauſe the lower End of her Axis lies upon it. And becauſe of its Inclination, the Axis will riſe and fall in the Socket Q, which is fixt in the Bar T, that carries the Moon round the Earth. To this Bar a ſmall Index U is fixt, which conſtantly ſhews the Moon's Place in her Orbit, among the Signs on the Plate V. Theſe Signs always keep parallel to themſelves, as they go round the Sun; but the inclined Plane P with its Nodes goes backward, ſo that each Node recedes through all the above Signs in almoſt 19 Years. On this inclined Plane there are two graduated Circles, the outermoſt whereof ſhews the Degrees and Parts of a Degree of the Moon's Latitude as it is North or South, and the innermoſt Circle ſhews her Diſtance from either of her Nodes.

That Node from which the Moon aſcends Northward above the Plane of the Ecliptic, is called the Aſcending

The Moon's Latitude.

cending or North Node; becauſe from it her Latitude (or Declination from the Ecliptic) is called *North Latitude Aſcending*, until ſhe comes to the higheſt Part of her Orbit, or to her greateſt North Latitude. From thence ſhe has *North Latitude Deſcending*, until ſhe comes to the South Node, ſo called, becauſe from it the Moon deſcends Southward below the Ecliptic, until ſhe comes to her greateſt South Latitude, in the loweſt Part of her Orbit: whence ſhe aſcends in South Latitude, until ſhe comes again to the North Node; and then aſcends from it in North Latitude, as before.

Aſcending and Deſcending.

Sydereal and Solar Time.

Two Indexes are put upon the Earth's Axis, and by the Earth's diurnal Motion they are carried round the Dial Plate X, which is divided into 24 Hours: The ſhorteſt Index ſhews the Sydereal, and the longeſt the Solar Time.

The Axis of the abovementioned Plates turn concentrically within one another, and come from the Wheel-work that is contained in the Box B, wherein the Sun's Axis is fixt, and by that Means the Solar Ray W conſtantly points toward the Earth's Center, as it is carried round the Sun.

Ecliptic.

The large Plate A is immoveable, becauſe on it is drawn the Ecliptic (which is the Standard of the whole Inſtrument) with its twelve Signs, each containing thirty Degrees: Within which is a Circle of the twelve Months, divided into their reſpective Days in ſuch a Manner, that the Degrees of the Ecliptic ſhew the Sun's Place, as they ſtand over theſe Days, throughout the whole Year. The next or innermoſt Circle contains 24 Hours, which begin with Aries at the 9th Day of *March*: their Uſe is to ſhew the Sun's right Aſcenſion in Time, every Day of the Year. All theſe are ſhewn by the annual Index Y fixed to the Box, and ſo goes round the abovementioned Circles, as the Box is by Hand turned round upon a Pin fixt in the Center of the large immoveable Plate.

Sun's Place.

His right Aſcenſion.

Why the Sun appears to go round the Ecliptic.

If we imagine this Circle of Signs to be raiſed up from the immoveable Plate, as high as the Centers of the Earth and Sun; it will repreſent the Situation of the Ecliptic, in whoſe Plane the Earth always moves about the Sun, which remains in the Center; but will appear, as ſeen from the Earth, to go thro' all the twelve Signs in a Year; becauſe he is ſeen by the Inhabitants of the moving Earth, who cannot perceive their own Motion, as they are carried along therewith.

General Phænomena.

While the Earth is carried once round the Sun by Hand, it ſhews all the beautiful Variety of the four Seaſons: and the Moon goes 12 Times and $\frac{1}{3}$ more round the Earth, from the Sun to the Sun again; ſhewing her Lunations and Phaſes: alſo her Latitudes, and Diſtance from her Nodes, as ſhe riſes above and falls below the Ecliptic in her inclined Orbit, whoſe Nodes go backward 19 $\frac{1}{3}$ Degrees every Year; and conſequently, in 18 $\frac{2}{3}$ Years, or little more, they go once backward thro' all the Signs and Degrees of her Orbit, without ever diſturbing the Poſition of her Signs; which, as above ſaid, ſtill keep their Paralleliſm as they go round the Sun, by looking toward their correſponding Signs in the Ecliptic. And in this ſmall Circle of Signs, the Moon's Place is ſhewn at any Time; as her Age is, on a Circle of 29 $\frac{1}{2}$ equal Parts upon the Box, round the lowermoſt Edge of her inclined Plane or Orbit.

On the Box are ſeveral Tables, for ſhewing the Place of the North Node, with the Moon's Age, Week-day, and Day of the Month, for any Time paſt or to come. By theſe Tables the Machine may be rectified in two Minutes to any given Time, ſo as to ſhew the Days of the Weeks and Months whereon the New and Full Moons, and Eclipſes of any Year, did or will happen.

The Sun is 13 Inches in Circumference, the Earth 9, and the Moon 2 $\frac{1}{2}$: the Box is 18 Inches long, and the large immoveable Plate is 27 Inches Diameter.

One Side of the Moon keeps always toward the Earth, and is engraven, to diſtinguiſh it from the other. She turns round her Axis within a black Cap, which ſhews her Phaſes to be different every Day, as ſeen from the Earth; but to the Sun ſhe always appears Full, and turns herſelf once round to him in every Lunation, having only one Day and one Night in that Time, equal in Length to 29 $\frac{1}{2}$ natural Days on our Earth.

The *Orrery* rectified.

To rectify this Machine for any given Year. Move the Box forward, until the annual Index comes to the Day whereon the Summer Solſtice falls in that Year; which is always on the longeſt Day thereof, and in the preſent Age, it is on the tenth of *June*. Stop there, and turn the Plate with the Moon's Signs upon it, until the Beginning of *Cancer* points directly toward the Axis of the Sun; and then the Earth's Axis will incline toward the Sun. Move the Box thence backward, until the Index comes to the Beginning of *January*: Then ſtop, and look in the proper Table for the Place of the North Node at that Time; to which Place, among the Moon's Signs, ſet the North Node of her inclined Orbit; by turning it either Way, until the Node be juſt under its proper Place in the Circle of Signs, as ſhewn by the Table.

The Orrery being once rectified, will ſhew the Phænomena depending upon its Rectification for many Years, reckoning every Revolution of the Earth round the Sun to be a Year; for in that Time, the annual Index goes quite round the Ecliptic and Month Circle.

Variation of the Seaſons.

As the Earth's Axis keeps its Paralleliſm in going round the Sun, 'tis plain that in Winter it will incline from him, in Summer towards him, and at the Equinoxes it will lean or incline neither to nor from the Sun, but ſidewiſe to him.

Vernal Equinox.

Move the Box until the annual Index comes to the 9th of *March*; the Sun will then appear as at the Beginning of *Aries*, and the Earth will be enlightned from Pole to Pole, becauſe its Axis inclines ſidewiſe to the Sun. In this Poſition, the Solar Ray ſhews the Sun to be Vertical to the Equator, which, with all its Parallels, go now equally thro' the Light and Dark Hemiſphere, by the Earth's diurnal Motion, and ſo make the Days and Nights then equal at all Places of the Earth: And this Equality would always continue, if the Earth turned round its Axis in that Place, without a progreſſive Motion.

But in moving the Box gradually forward, the North Pole by Degrees advances more and more into the enlightened Hemiſphere, and the South Pole recedes from it, as the annual Index advances forward from *March* toward *June*. The Solar Ray quickly leaving the Equator, approaches ſlower and ſlower toward the Tropic of *Cancer* every Day, until it ſtands over the ſame, when the

Index comes to the tenth of *June*, or Beginning of *Cancer* in the Ecliptic. It is now Summer, and the longeſt Day in all the Northern Hemiſphere, as it is Winter and the ſhorteſt Day in the Southern. And if the Earth was to remain in this Poſition, continuing to turn round its Axis, the Days would always be of the ſame Length at the ſame Places. On the North Side of the Equator there would be a continual Summer, as on the South Side there would be continual Winter, the Southern Hemiſphere being as much turned away from the Sun, as the Northern inclines toward him. The Days are gradually longer, as the Places are more remote from the Equator on the North Side to the Arctic Circle, and on the South Side the contrary happens. All the Arctic Circle is now entirely in the Light, and the Antarctic Circle in Darkneſs, the Sun not ſetting to any Place within the one, nor riſing to any Place within the other.

Summer Solſtice.

From this uncomfortable Situation of the Inhabitants of the Southern Hemiſphere, move the Earth forward, and you'll perceive the North Pole gradually turning away from the Sun, as the South Pole approaches towards him at the ſame Rate: And the Solar Ray quickening its Pace every Day from the Tropic of *Cancer* toward the Equator, as the Summer is on the Decline: And the Days ſhortening as the Nights lengthen, in the Northern Hemiſphere; while the contrary happens in the Southern, until the annual Index comes to the 12th of *September*, and the Solar Ray points directly to the Equator. The Earth being then enlightened from Pole to Pole, makes equal Day and Night again at all Places upon it. And this Equality would always continue, if the Earth's progreſſive Motion was ſtopt, and it could turn round its Axis without falling to the Sun.

Autumnal Equinox.

But bring the Earth forward in its annual Courſe, and you'll immediately ſee the Sun ſet to the North Pole, and riſe to the South Pole; as the Solar Ray leaves the Equator, going from thence every Day ſlower and ſlower, by moving the Earth uniformly forward. The Winter now approaches, and Days ſhorten in the Northern Hemiſphere, as the Reverſe happens in the Southern; until the Index comes to the 10th of *December*, and the Sun, as ſeen from the Earth, appears at the Beginning of *Capricorn*; over whoſe Tropic the Solar Ray then ſtands vertically. And as the Sun has removed ſo far from the Equator Southward, as the Polar Circles are diſtant from the Poles, 'tis plain that the Antarctic Circle muſt now fall entirely within the enlightened Half of the Earth, and the Arctic Circle without the ſame. It is now Winter, and the ſhorteſt Day in the Northern Hemiſphere; as it is Summer and the longeſt Day in the Southern; and would ſtill be ſo, if the Earth's annual Motion would ſtop here, and the diurnal continue.

Winter Solſtice.

But as the Earth goes forward without ſtopping among the Signs, the Solar Ray leaves the Tropic of *Capricorn*, and returns back every Day with a quicker Pace toward the Equator, as the South Pole recedes from the Sun, and the North Pole advances toward him at the ſame Rate. When the Ray comes to the Equator, the Earth is enlightened from Pole to Pole: and as the Equator, and all its Parallels, go equally thro' the Light and the Dark, the Days and Nights are again equal at all Places; the Earth being at the Beginning of *Libra*, and the Sun, as ſeen from it, appearing at the Beginning of *Aries*.

The Cauſe of the different Lengths of Days and Nights, and Change of Seaſons.

Thus the Paralleliſm of the Earth's inclined Axis, as it turns round the ſame, and its ſimple Motion in the Ecliptic about the Sun, ſolves all the beautiful Variations of the Seaſons, as they continually change: and likewiſe the different Lengths of Days and Nights at all Places, ſave under the Equator and Poles, where they are always the ſame: there being 365 equal Days and Nights at the Equator, becauſe all its Parts turn themſelves to and from the Sun ſo many Times in a Year: whereas at the Poles there is but only one Day and one Night in the whole Year, becauſe the Sun ſhines conſtantly for half a Year, without ſetting at each Pole in its Turn, and is as long abſent from it, riſing to the one, when he ſets to the other.

Take off the Earth, with its inclined Axis, and put on one in its Place whoſe Axis is perpendicular to the Plane of the Ecliptic, then move the Earth round the Sun, as before, and you'll ſee the Seaſons to be always the ſame, without any Alteration, and the Days and Nights to be ſtill of the ſame Length at all Places throughout the whole Year. Only at the Poles there is hardly either Day or Night, the Sun neither riſing above, nor ſetting below the Horizon; but going round the ſame continually with one Half of his Diſc in View; the Half that is ſeen from one Pole is never ſeen from the other. This is what would really happen, if the Earth's Axis had no Inclination to its annual Path; and hence, the Torrid Zone would be ſo ſcorch'd with Heat, as to be uninhabitable; and the Frigid Zones would be uninhabitable by reaſon of the great Cold.

How the Earth's Inhabitants caſt their Shadows.

In ſeveral different Parts of the Earth at Pleaſure, as the Equator, Tropics, and Parallel of *London*, or any Place put ſmall Pins, to repreſent ſo many Inhabitants, each ſtanding perpendicular to the Horizon of his own Place; this done, put the Earth upon its inclined Axis, and fix it on the Machine as before: Take away the Sun, and put a Candle or Lamp in his Place, which will enlighten this fictitious Earth, as the true Sun does the real one. Bring the Earth forward, until the annual Index comes to any Day of the Year that you pleaſe; ſtop there, and turn the Earth on its Axis, until the Meridian of either Inhabitant looks directly toward the Candle, and ſet the Hour-Index below the Earth to XII on its Dial Plate: Then turn the Earth round its Axis, and you'll ſee how each Inhabitant caſts his Shadow, both in the Forenoon and Afternoon; with the Time of Sun riſing and ſetting, as the Pin comes into the enlightened Hemiſphere, and goes out of the ſame. At the Equinoxes, the Pin on the Equator will have no Shadow at Noon; as at the Summer Solſtice on either Tropic, its Pin will have no Noon-Day Shadow: but all the Pins without the Tropics will have Shadows, the longer as they are the further North or South.

A plain way of ſhewing the different Seaſons.

Move the Earth gradually round the Sun or Lamp, and you will have all the different Seaſons exhibited in the moſt plain and demonſtrative Manner, by the different Poſitions of the Earth's Axis to the Sun in its annual Motion.

Sydereal Time.

The fixed Stars paſs over the Meridian every Day or Night, about four Minutes ſooner than on the preceding; and conſequently, in a Year, any given Star will paſs over the Meridian once more than the Number of Natural Days in a Year, as meaſured by the Sun. This is occaſioned by the Earth's going round the Sun the ſame Way that it turns round its Axis, namely, from Weſt to Eaſt: But as I ſhall have Occaſion, in the following Paper, to handle this more fully, I need not inſiſt upon the Cauſe of it here.

To ſhew the Sydereal Time at any Hour, upon any Day of the Year, by the Orrery; move the Box till the annual Index comes to the given Day, then ſtop; and turn the Earth on its Axis, until the graduated Arch comes to the Solar Ray; keeping it in that Poſition, ſet the longeſt Index on the Earth's Axis to [Mid-day] XII on the Hour Circle; then turn the Earth till this Index comes to the given Hour, and the ſhorteſt Index will then be upon the Sydereal Time, as ſhewn by a fixed Star which paſſed over the Meridian with the Sun at the Vernal Equinox; there being no Difference on that Day between the Solar and Sydereal Hours; but on the tenth of *June* there is 6 Hours difference, for then the Sydereal Noon will be at Six o' Clock in the Morning; on the twelfth of *September* there will be 12 Hours difference, the Sydereal Noon happening then at Midnight; on the tenth of *December* there will be 18 Hours difference, the Sydereal Noon having been at Six o' Clock in the Morning of the preceding Day; and ſo upon the ninth of *March* the Difference being 24 Hours ſooner, or juſt a Day and a Night, brings the Sydereal and Solar Noon to the ſame Time, or Middle of the Day again.

If the Earth had no annual Motion, the Solar and Sydereal Time would always be the ſame, becauſe the Sun would never change his Poſition with regard to any of the fixed Stars.

Horizon of any given Place.

To put the Horizon upon the Earth, ſo as to repreſent the rational Horizon of any given Place thereon; take with your Compaſſes 90 Degrees upon the Equator (which is equal to its Diſtance from any of the Poles) and ſetting one Foot in the given Place, turn the other round about the Globe, fixing the Horizon ſo as the moving Foot may juſt touch its Surface equally round on the Globe; the Meridian of the Place cutting it in the South Point: Thus ſhall the given Place be in the Zenith of the Horizon which divides the Globe in two equal Parts, called th upper and lower Hemiſpheres; and the 90th Degree o the graduated Arch will ſtand directly over the Vertex o the Place.

An extenſive Problem.

The Horizon being thus fitted on the Globe fo any given Place, and the Machine rectified; yo may ſee, on any Day, at what Time the Sun an Moon will riſe and ſet, with their Amplitude Declinations, Places in the Ecliptic, Right Aſcenſions, Diſtance from the Moon's Nodes, and A titudes on the Meridian: alſo the Moon's Latitu or Declination from the Ecliptic, with the Plac of her Nodes, and Time of her coming to the M ridian: And laſtly, over what Places of the Ear the Sun and Moon are Vertical, at any Hour wha ſoever. For,

If you (by moving the Box forward) bring the annu Index to any Day of the Year you pleaſe, in the Circ

Sun's Place.

of Months, it will ſhew the Sun's Place in the Eclipt

His Right Aſcenſion.

for that Day; and his Right Aſcenſion in the Circle 24 Hours. Then (without moving the Box) turn t Earth on its Axis, until the graduated Arch comes to t Solar Ray, and ſet the Solar Index, which is the longe one upon the Earth's Axis, to XII at Noon on the Ho Circle; which done, turn the Earth round its Axis Eaſ ward, and obſerve where the Solar Ray cuts the Horizo

His Amplitude, and Time of riſing.

upon the eaſtern Side, for there it ſhews the Sun's Amplitude at riſing; and the Solar Index will then point o the Time thereof upon the Hour Circle. Turn on, an as the Horizon ſinks lower and lower under the Ray, t Sun appears to be riſing higher and higher to the give

His Meridian Altitude, and Declination.

Place, until he comes to the Meridian, where the Ra at once ſhews his Declination and Meridian Altitude upo the graduated Arch. Continue turning, and as the Arc leaves the Ray in going 'Eaſtward, the Sun appears o the Weſt of the Meridian, deſcending lower and lower as the weſtern Edge of the Horizon riſes higher and higher,

His Amplitude, and Time of ſetting.

until the Ray cuts it as the Sun ſets, at his ſettin Amplitude; and the Time of his Setting is ſhewn by th Solar Index, on the Hour Circle. Look

Moon's Age.

Her Place in her Orbit, alſo her Latitude and Diſtance from her Nodes.

Her Diſtance from the Sun.

Her Amplitude, and Time of riſing; with her Altitude and Declination on the Meridian; alſo her Amplitude and Time of ſetting.

Her Right Aſcenſion.

Look in the proper Table on the Box for the Moon's Age on the ſaid given Day, which is there found by Inſpection; and without moving the Box, ſet the Moon to the ſame Day of her Age in the Circle of 29½ equal Parts; and the ſmall Index (which is fixed to the Bar that carries her round) will ſhew in what Sign and Degree ſhe then is, in her own Orbit; as the lower End of her Axis will ſhew her Latitude on her inclined Plane, as it is North or South, Aſcending or Deſcending; and alſo her Diſtance from her North and South Nodes at that Time. You may alſo ſee her Diſtance from the Sun, by obſerving what is the Sun's Place in the Ecliptic, and counting from the like Place in the Moon's Orb to the Place where ſhe then is: In this Manner you may alſo ſee the Sun's Diſtance from either of the Moon's Nodes. Now turn the Earth on its Axis, as before, and you'll ſee on what Point of the Compaſs the Moon riſes; the Time being ſhewn on the Hour Circle by the foreſaid Index; and in paſſing over the graduated Arch, her Altitude and Declination is ſhewn; as the Time of her coming to the Meridian is then pointed out by the ſaid Index on the Hour Circle: And when, by turning the Earth, ſhe comes to the weſtern Side of the Horizon, ſhe ſhews her ſetting Amplitude thereon; and the Hour Index ſhews the Time of her ſetting. If you look for the ſame Sign and Degree in the Ecliptic, in which the Moon is in her Orbit, and obſerve what Hour or Part of an Hour anſwers thereto, within the Circle of Months, it gives you the Moon's Right Aſcenſion.

Her *Phaſes* and Motion round her own Axis.

Her Day and Night equal to a whole Lunation.

In ſhewing theſe Phænomena, a Moon without a Cap is made uſe of; having a ſmall Pin fixt in the Middle of that Side of her which always keeps toward the Earth: This Pin is of the ſame Uſe in determining her Amplitude, Altitude, and Declination, as the Solar Ray is in ſhewing the like Phænomena of the Sun. But in ſhewing her *Phaſes*, a Moon with a Cap is uſed; and either of theſe may be taken away, and the other put on, in about two or three Seconds of Time. The Moon ſtill keeps the ſame Side toward the Earth, and turns round her Axis within her Cap, which always faces the Sun; and in every Lunation ſhe turns herſelf round to the Sun, in which Time ſhe has juſt one Day and one Night, equa in Length to 29½ Natural Days on our Earth; her Da and Night being conſtantly of an equal Length.

To what Places the Sun and Moon are vertical.

The Moon ſtanding over the Day of her Age, as a bove; turn the Earth on its Axis until the Hour Inde points to any Hour of the Day or Night at the give Place; then ſtop, and you'll ſee by the Solar Ray, an Pin fixed in the Moon, to what Places of the Globe th Sun and Moon are Vertical at that Time.

Thus you may ſee all the abovementioned Phænomen for any Day of any Year whatſoever, by bringing th annual Index to the Sun's Place on the given Day, an then proceeding in the above Manner; all which may b done in a few Minutes, as the Machine is ſo eaſily rec fied.

Moon's Periodical and Syncdical Revolution.

By the Circle of the Moon's Signs, and that of h Age, the Difference between her Periodical and Synodic Revolution is plainly ſhewn: For if the Moon be ſet b Hand to her Conjunction with the Sun, or over the Day on the Circle of 29½ equal Parts, and then her Pla in her Circle of Signs be obſerved; move the Box fo ward, and in the Time that the annual Index goes ov 27⅓ Days in the Circle of Months, you'll ſee that th Moon has gone thro' all the Signs and Degrees of her O bit, to the ſame Place from whence ſhe ſet out at the la Conjunction; and will then be ſtanding over 27⅓ Da of her Age, in which Time ſhe finiſhes her Periodic Revolution, having gone thro' the twelve Signs; and tha is as much, as by the Earth's annual Motion, the Sun appears to do in a Year: But ſhe has not yet got to her nex Conjunction; for the Box muſt be moved till the annua Index advances 2⅙ Days forward, which will cauſe th Moon to travel forward 28½ Degrees in her Orbit; an this will bring her to her next Conjunction, or betwee the Earth and the Sun again, quite round the 29½ Day of her Age; and her Cap with her Motion on her Axi within the ſame, will have ſhewn all her different *Phaſ* to the Earth; and will have kept her always Full, as ſeen from the Sun.

The Reaſon why they differ.

The Difference between the Moon's Periodical and Sy nodical Revolution, ariſes from the Earth's going forwar in the Ecliptic, almoſt a whole Sign, or twelfth Part thereof, in the Time that the Moon goes round the Earth, in her Orbit; and therefore ſhe never finds the Sun at any Conjunction where ſhe left him at the laſt; becauſe he will appear to have advanced as far in the Ecliptic as the Earth has really done; and therefore, when the Moon has gone from any Conjunction quite round her Orbit, ſhe muſt yet travel 28 ½ Degrees forward to overtake the Sun again.

Familiarly ſhewn by the two Hands of a Watch.

This may be very well underſtood by the Hour and Minute Hands of a Watch, going round the Dial Plate; which is divided into 12 equal Parts or Hours, as the Ecliptic is divided into 12 Signs. Here, let the Hour Hand repreſent the Sun, and the Minute Hand the Moon; and ſuppoſe them together, or in Conjunction at XII; from which Place, both Hands go forward like the Sun and Moon; but when the Minute Hand has finiſhed its Periodical Revolution, by going round the Dial Plate to XII again, it finds not the Hour Hand there; which, in that Time, has made a twelfth Part of a Revolution forward, by going from XII to I; and will be overtaken by the Minute Hand a little after I, where it finiſhes its Synodical Revolution. To thoſe who have not an Opportunity of ſeeing the Machine, this familiar Example will give an indifferently good Idea of this Phænomenon; but it is not a true Repreſentation thereof; becauſe the Minute Hand goes too ſlow to repreſent the Moon's Motion, when compared with that of the Sun, as ſhewn by the Hour Hand: For, while the Hour Hand goes once round the Dial Plate, the Minute Hand makes only 11 Conjunctions with it; whereas the Moon makes 12 Conjunctions and ⅓ of one more with the Sun in a Year; or in the Time that (by the Earth's annual Motion) he appears to go once round the Ecliptic.

Moon's Sydereal Day.

The Moon turns round her own Axis preciſely in the Time that ſhe goes round the Earth, or through all the Signs and Degrees of her Orbit; which, as aboveſaid, is in 27⅓ Days; and ſo, by ſhewing herſelf all round to any given fixt Star in or near the Ecliptic, ſhe finiſhes her Sydereal Day.

Her Solar Day.

But her Solar Day (containing both a Day and a Night) is not compleated until ſhe revolves

round her Axis from the Sun to the Sun again; or fron
any particular New Moon to the next following; i
which Time, ſhe ſhews herſelf all round to the Sun
This is made as plain by the Orrery, in the followin
Manner, as any one can deſire.

How both are ſhewn by the *Orrery*.

Move the Box forward, until the Moon is oppoſite t
the Sun; that is, when all the half of her next the Eart
appears without her black Cap, and ſhe ſtands a littl
ſhort of the 15th Day of her Age: Then ſhe will ap
pear with a full Orb, as ſeen both from the Earth an
the Sun. In the Middle of this Orb, Face, or Diſc (ca
it which you pleaſe) is a ſmall black Spot repreſenting a
Inhabitant, who at that Time has the Sun in his M
ridian. In the Plane of this Meridian, fix a Pin in th
Wall of the Room; which may be done by ſtretching
Thread from the Moon, over the Earth and Sun, to th
Wall; and where the Thread touches it, there fix th
Pin; whoſe Head will repreſent a Fixt Star, in that Lu
nar Meridian with the Sun: And remember that the fu
ther the Pin is from the Machine, ſo much the bette
and nearer to Nature, is the Experiment. This don
move the Box ſlowly forward; and the Lunar Spot (
Inhabitant will turn away both from the Sun and Sta
toward the eaſtern Edge of the Cap; and the Sun, a
ſeen from the Spot, will ſeem to deſcend lower an
lower, till the Moon comes to her third Quarter; an
then the Sun will ſet to the Spot, as it goes in below th
Cap, when one half of the Moon's Side next the Ear
diſappears, becauſe it is hid in the dark. Move on t
the Moon comes to her Conjunction, when all the Sid
of her next the Earth diſappears quite to it, being th
Time of New Moon; and the Spot or Inhabitant bein
then in the Middle of the Dark Hemiſphere, it is Mid
night to him. But he will ſee the Earth's whole enlight
ned Side appearing Full, and ſhining ſtrongly upon him
becauſe to him it is then in Oppoſition to the Sun; a
the Moon is to the Earth's Inhabitants when ſhe is Full
Continue to move the Box forward, until the Moo
comes to her firſt Quarter, and then you'll ſee the Spo
or Inhabitant juſt coming out from below the Cap into
the Light; and the Sun will appear as riſing to him

Th

The Side of the Moon next the Earth being then half in the Light and half in the Dark. Continue the Motion, and the Spot will advance more and more into the Light, as the Sun appears to riſe higher and higher to it. But if you now carefully obſerve the Spot, you'll ſee it point towards the Pin or Star when the Moon comes to about 12½ Days on the Circle of 29½ equal Parts; or 2 Days and 4 Hours ſhort of her Oppoſition, from which you began to reckon; and here her Sydereal Day is finiſhed. But the Spot will not point towards the Sun, until the Moon be Full; and then the Sun will be in the Meridian of the Spot, which finiſhes her Solar Day. The Earth being then between the Moon and the Sun, becomes inviſible to her Inhabitants, as the Moon does to the Earth's Inhabitants at her Conjunction or Change. Thus, a New Moon anſwers to a Full Earth; as a Full Moon does to a New Earth: When the Moon is in her third Quarter, ſhe ſees the Earth in its firſt Quarter; and *vice verſa*.

A New Moon anſwers to a Full Earth, and a Full Moon to a New Earth.

The Moon is moſt enlightned at her Conjunction, being then neareſt to the Sun; though ſhe diſappears to the Earth at that Time: And is leaſt enlightned at her Oppoſition, becauſe ſhe is then fartheſt from the Sun; though at that Time ſhe appears moſt enlightned to the Earth, becauſe ſhe ſhines with a Full Orb or Diſk upon it.

A Paradox ſolved.

Although we have no Opportunity of meaſuring Time by the Lunar Spots, becauſe the Moon ſtill keeps the ſame Side obverted to the Earth; yet the Earth may be a very good Dial to one half of the Moon; becauſe the Inhabitants thereof will have it continually in View; and ſo, by the Approach of the Sun or Stars towards it, by the Name of the Pole that it ſhews, and by the ſwift Motion of its Spots, ſuch as Seas, Continents, Snowy Places, and the like; it divides the Lunar Day and Night into a ſufficient Number of Parts; and will be of good Uſe in meaſuring Time to the Lunar Inhabitants on the Side next the Earth; but can be of no Uſe to thoſe on the other Side, becauſe unleſs they travel from their reſpective Places, they can never ſee it.

The Earth a good Dial to the Moon.

In the Courſe of a Lunation, the Earth, as ſeen from the Moon, appears only to turn $28\frac{1}{2}$ Times round its Axis; for by her going round the Earth the ſame Way that it turns round its Axis, it loſes the Appearance of one Turn to her, in every Lunation.

The Sun appears much the ſame in Magnitude and Light, both to the Earth and Moon; and to the Earth's Inhabitants, the Moon appears to be about the Largeneſs or Bulk of the Sun.

According to Sir ISAAC NEWTON,* the Diameter of the Moon is to the Diameter of the Earth, as 100 is to 365. Therefore, Circles being in ſuch Proportion to one another as the Squares of their Diameters; it i plain that the Earth, as ſeen from the Moon, will appea to be by much the largeſt Body in the Univerſe; for it

The Earth's Bulk and Light, as ſeen from the Moon.

Face or Diſk will appear at leaſt 13 Times as large a the Sun's; and conſequently, the Earth will reflect Light upon the Moon 13 Times greater than the Moo does upon the Earth; or ſtrictly ſpeaking, $13\frac{3225}{10000}$ Time as much, ſuppoſing the Reflexions to be in the ſam Proportion to one another as the Diſks are.

No Change of Seaſons in the Moon.

In the Moon there is hardly any Change of Seaſons her Axis being but very little inclined to the Plane o the Ecliptic: And the whole Diameter of her Orb, a ſeen from the Sun, ſubtends but an Angle of abo 22 Minutes of a Degree; although it is in Lengt 480,000 *Engliſh* Miles. Conſequently, her riſing abo or falling below the Ecliptic $5\frac{1}{3}$ Degrees, as her Orbit i inclined thereto, will not, as ſeen from the Sun, cau her to riſe and fall 2 Minutes of a Degree above or below the Ecliptic; and therefore, on that Account, th Sun will not ſenſibly remove from her Equator. Ye the Inhabitants of the Moon will not want Means fo

How the Moon's Inhabitants may be ſuppos'd to meaſure the Length of their Year.

knowing the Length of their Year, though their Method and ours in determining the ſame Length of Tim muſt differ: For, we can do it by the Times that ou Equinoxes happen; but the *Lunarians* having always equal Days and Nights, are deſtitute of ſuch a Method And therefore, we may ſuppoſe they will do it by obſerving the different Poles of our Earth, as the one begins to be enlightned, and the other to diſappear, always at our Equinoxes; they being conveniently poſited for ſeeing great Tracts of Land (no Doubt always covered with Snow) about our Earth's Poles, which are undiſcovered by us. Hence we may reaſonably conclude, that the Year is of the ſame Length both to the Inhabitants of the Earth and Moon; we having $365\frac{1}{4}$ Days, and they only $12\frac{7}{19}$; every natural Day in the Moon being as long as $29\frac{1}{2}$ on the Earth.

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* Princip. l. III. prop. 37. cor. 4.

Almoſt every third Year is a Leap-Year in the Moon.

This odd Fraction of a Day in every *Lunarian* Year, will occaſion a good deal of Trouble to the Moon's Inhabitants, in keeping their Calendar right. For, in the firſt Place, during 9 Years, they will add a Day to the End of every third Year; which will be a Leap Year to them, as every fourth Year is to us. But becauſe 7 is more than a third Part of 19, there will be an Error of about $\frac{2}{19}$th Parts of a Day to them (equal to 3 Days and $2\frac{1}{2}$ Hours with us, in round Numbers) every Year. And in the ſecond Place, they will find that in 10 Years the Fraction will be ſomewhat more than a compleat Natural Day, by running up ſo much every Year. Conſequently, at any given Time in the anniverſary Return of the ſame Day, the Sun will be at leaſt 10 Degrees from the Place of the Ecliptic wherein he was at that Time on the Year before. For $\frac{7}{19}$th Parts of a Lunation is almoſt equal to 11 Days with us; in which Time, the Sun moves almoſt 11 Degrees in the Ecliptic.

Her Calendar very troubleſom.

Limits of the Eclipſes.

On the Moon's inclined Plane or Orbit, at 18 Degrees Diſtance from her Nodes on each Side, is marked a ſmall Sun; and at 12 Degrees Diſtance, a ſmall Moon: Theſe are the Limits of Eclipſes, the firſt, of the Sun; and the other, of the Moon. They are ſet at the above Diſtances, becauſe the Sun is eclipſed if at New Moon he be within 18 Degrees of either Node; and the Moon muſt undergo an Eclipſe if at the Full ſhe be within 12 Degrees thereof. Thus, Eclipſes of the Sun and Moon depend entirely upon the Poſition of the Moon's Nodes to the Sun, at New and Full Moon.

When the Moon is in either of her Nodes, ſhe is then in the Plane of the Ecliptic; and this happens at leaſt twice in every Lunation: In ſome, it will happen thrice; but that is ſeldom, and only when the Moon has little more than a Day's Journey from her Conjunction to her neareſt Node.

Why an Eclipſe of the Sun may be inviſible in the Day-time.

If the Moon's Orb lay altogether in the Plane of the Ecliptic, there would be an Eclipſe of the Sun (as it is very improperly called) at every New Moon; becauſe the Moon's Shadow then paſſing over ſome Parts of the Earth, would deprive them of the Sun's Light. But becauſe the Sun is a great luminous Body, and the Moon a ſmall one, having no Light of her own, her Shadow will be Conical; and can only cover a ſmall Part of the Earth at once. And therefore, there would be many ſuch Eclipſes Inviſible, though at Noon-Day, to a great many Places of the Earth. The Moon, at every Time of her being oppoſite to the Sun, would paſs through the Earth's Shadow; which would cover her, if her Diameter was three Times as large as it really is; and then ſhe would ſuffer a *real* Eclipſe; total to all thoſe of the Earth's Inhabitants, who would have the Opportunity of ſeeing it.

Why Eclipſes happen not at every New and Full Moon.

But becauſe the Sun and Earth are always in the Plane of the Ecliptic, and the Moon's Orb is inclined to it, and cuts it only in the Nodes, it is plain there can be no Eclipſes of the Sun or Moon, but when a right Line paſſing through the Nodes, would, if continued, paſs either through or nearly by the Sun, at the Time of New or Full Moon. And from the Time that this happens, till it does ſo again, is about 173 Days, or near half a Year; ſave what Allowance is to be made for the ecliptick Limits abovementioned.

When Eclipſes happen in general.

Their Number ſhewn for any Year.

To know the Number of Eclipſes, and the Days whereon they will happen, in any Year: Rectify the North Node at the Beginning of any given Year, to its Place in the Signs of the Moon's Orbit, as directed in Page 22; and from the Table of the Moon's Age on the Box, take out the Days of all the New and Full Moons in that Year: Then move the Box forward, obſerving carefully when the * Line of Conjunction points toward any Place in the Moon's inclin'd Orb between the little Sun and either of the Nodes, when the annual Index is on the Day of any New Moon in the Circle of Months; for on that Day, the Sun will be eclipſed. Obſerve likewiſe when the Line of Conjunction points any Way between the little Moon and either of the Nodes, when the Index points at the Day of any Full Moon; for, on that Day, the Moon will be eclipſed. Thus you may ſee how many Eclipſes will happen in any Year, and on what Days of the Months they will fall; as alſo in which of the Nodes the Sun or Moon will be eclipſed: And by their Diſtance from the Node, the Number of Digits (eſpecially in Eclipſes of the Moon) may be eſtimated; for, if the Moon's Latitude be leſs than half a Degree North or South at her Oppoſition to the Sun, ſhe will be totally eclipſed; otherwiſe, the Eclipſe will only be partial at that Time.

And on what Days they will be.

Moon's Eclipſe. When Total and when Partial.

To know at what Places of the Earth any Lunar Eclipſe will be viſible; move the Box till the annual Index comes to the Day of the Month whereon that Eclipſe happens; then ſtop, and ſet the Moon directly over the Line of Oppoſition, a little ſhort of the 15th Day of her Age: Which done, turn the Earth on its Axis until the graduated Arch comes to the Solar Ray, and ſet the Hour Index to XII at Noon on the Hour Circle. Then turn the Earth till the Index comes to the Time of the Middle of the Eclipſe at the given Place; ſtop there, and obſerve what Hemiſphere of the Earth looks toward the Moon; for, at all Places included within that Hemiſphere, the Eclipſe will be viſible: The Inhabitants of the Place over which the Moon ſtands, will ſee her eclipſed vertically in their Meridian; and if with a Pair of Compaſſes you take 90 Degrees from the Equator, and ſetting one Foot in that Place, turn the other quite round the Globe, and it will paſs over all thoſe Places

To know all the Places of the Earth whereat any Eclipſe of the Moon will be viſible.

Where ſhe is eclipſed in the Zenith.

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* So called, becauſe it is drawn upon the Surface of the Box from under the Center of the Earth to the End of the Sun's Axis below his Center; and therefore, when the Moon ſtands over that Line, ſhe is in Conjunction with the Sun.

Where in the Horizon; and over what Point thereof in any given Place.

that have the Moon in their Horizon at the Middle of the Eclipſe. Thus you may ſee all the Places to which the Moon is juſt riſing or ſetting at the Middle of the Eclipſe; and over what Point of the Compaſs ſhe then is, at any given Place in the Hemiſphere where it is viſible.

Sun's Eclipſe.

As for Eclipſes of the Sun, it is not ſo eaſy to ſhew by the Machine at what Places they will be viſible; eſpecially what Number of Digits will be obſcur'd at any given Place; although it very well ſhews on what Days of the Year they happen, and when they fall on the North or South Side of the Equator, or on the Equator itſelf. Yet, ſuch as have a Calculation of an Eclipſe for any given Place, and are deſirous to ſee all the Places on a Globe where that Eclipſe will be viſible; may ſatisfy their Curioſity by obſerving the following Method.

At what Places viſible.

Move the Box forward, until the annual Index comes to the Day on which the Eclipſe happens; then turn the Meridian of the given Place toward the Solar Ray, and ſet the Hour Index to XII. Which done, turn the Earth on its Axis until the Index comes to the Time of the Middle of the Eclipſe, on the Hour Circle; ſtop there, and the Solar Ray will ſtand over the Place of the Earth to which the Sun is vertical at that Time. Then ſay by the Rule of Proportion, As the Semidiameter of the Earth's Diſk is to 90 Degrees, ſo is the Moon's Latitude (found by her Poſition on the inclined Plane, or by Calculation) to the Number of Degrees that the Penumbra's Center is diſtant from the Place juſt under the Sun; which is North or South as the Moon's Latitude is North or South at that Time. Then, as the Semidiameter of the Earth's Diſk is to 90 Degrees, ſo is the Semidiameter of the Penumbra to the Number of its Degrees of Breadth ſought; which laſt Number of Degrees, take in your Compaſſes from the Equator; and with that Diſtance, ſetting one Foot in the Place where the Penumbra's Center falls on the Globe, turn the other round, and it will take in all the Parts of the Earth to which the Eclipſe is viſible at that Time. To find the Digits eclipſed at thoſe Places, draw a right Line on a Paper

And what Number of Digits are eclipſed at thoſe Places.

a Paper or Board, equal to the Extent of your Compaſſes or Semidiameter of the Penumbra, and divide it into 12 equal Parts; then putting a black Lead Pencil into one Foot of your Compaſſes, take off theſe Diviſions, and from the Penumbra's Center make 12 parallel Circles on the Globe; which can be eaſily rubbed out again. Then, thoſe People who are juſt under the Penumbra's Center, will have either a total or annular Eclipſe of the Sun: Thoſe who dwell upon the Verge of the Circle next the Center, will have 11 Digits eclipſed, and but one enlightned: Thoſe upon the ſecond Circle will have 10 Digits eclipſed, and two enlightned: Thoſe under the third will have 9 Digits eclipſed and three enlightned, *&c.* This pleaſant mechanical Operation can be performed in a very little Time; having the neceſſary Calculations, which may be eaſily had of thoſe, who make the Calculating of Eclipſes a Part of their Buſineſs. I forbear ſhewing the Method of ſuch Calculations here, becauſe it would not only be a Digreſſion from my preſent Purpoſe, but would alſo ſwell the Bulk of theſe Papers far beyond what I have intended.

How our Solar Eclipſe appears to the Lunar Inhabitants.

When the Sun is eclipſed to any Part of the Earth, the Lunar Inhabitants will ſee a dark reddiſh Spot travelling over the Earth, the ſame Way that it turns round its Axis, but with a greater Velocity than the Spots of the Earth move. This being the Shadow of the Moon upon it, all Places that the Shadow goes over, will have the Sun eclipſed to them. Conſequently, as our Earth is a Moon to our Moon, the Lunar Inhabitants will never have ſo much of their Moon darkened by the Shadow of their own Globe as to affect their Moon-Light at that Time, in the leaſt Manner ſenſible to them.

A Lunar Eclipſe to the Earth is a Solar Eclipſe to the Moon.

When the Moon is totally eclipſed to our Earth, all the Lunar Inhabitants on the Side next the Earth, have the Sun totally eclipſed to them; which will be of as long Duration as the Parts of the Moon continue dark, and that will be for ſome whole Hours; although to us no total Eclipſe of the Sun laſts above four Minutes. To thoſe on the other Side or Hemiſphere of the Moon, the Sun is ſet; and ſo they are always depriv'd of ſeeing a Solar Eclipſe, becauſe it never happens in the Moon ſave when ſhe is Full to us; and then the Side on which the Earth's Shadow falls not, is turned away from the Sun.

Though the Sun be totally eclipſed to the Moon, yet ſhe is not quite deprived of Light.

When the Moon is partially eclipſed to the Earth, ſome of the Lunar Inhabitants will have a partial, and others a total Eclipſe of the Sun; as they are in thoſe Parts of the Moon that are not, or that are, covered by the Earth's Shadow. But as the total Eclipſe, where it happens, is of long Continuance, the *Lunarians* will have this Convenience; that becauſe the Sun's Rays are refracted by the Earth's Atmoſphere, no Part of the Moon will be quite in Darkneſs; for if it was quite dark, we could not ſee any Part of the Moon in the Time of her Eclipſe.

Why thoſe Parts of the Earth are quite deprived of Light where the Sun is totally eclipſed.

The Reaſon why an Eclipſe of the Sun occaſions a total Darkneſs to thoſe Parts of the Earth whereon the Moon's Shadow falls, when her apparent Magnitude exceeds the Sun's, is, that the Moon has no Atmoſphere; or if ſhe has any, it is ſo very thin or rare, as not to be capable of refracting the Sun's Rays; and therefore none of them can enter into the Moon's Shadow.

An Error commonly practiſed in making of Orreries.

Inconvenience thereof.

Here, by-the-bye, without being the leaſt prejudiced in Favour of my own Orrery; or having the leaſt ill-natured Meaning towards other Orrery-Makers; I cannot avoid taking Notice of a very great Error that is commonly practiſed in making of ſuch Machines: Namely the too great Inclination of the Moon's Orbit, which is uſually about three Times as great as it is in the Heavens. And the only Reaſon of its being made ſo, is to ſhew the Eclipſes by a Lamp; and to make the Moon's riſing above and falling below the Ecliptic, more ſenſible to the Eye. But this is deſtroying one Truth to explain another; and renders it impoſſible, for ſuch a Machine, to ſhew when the Moon either riſes or ſets; and ſo, her Amplitude cannot be ſhewn; nor her Altitude on the Meridian; nor the Place of the Earth ſhe is vertical to, at any Time, except when ſhe is in her Nodes. And even in ſhewing Eclipſes by a Lamp, it makes many more than happen in Nature; notwithſtanding that a leſs Earth and Moon are put on, than what are uſed for other Purpoſes. Indeed, if the Moon's Orbit be made to cut the Ecliptic at an Angle of 15

Degrees, which is almoſt three Times as great as it ſhould be; and its Diameter be half a Foot, which is more by a great deal than it can be where the inferior Planets are crowded together in a Machine that takes in the ſuperior ones; and if the Moon's Diameter be a tenth Part of an Inch, and the Earth's in Proportion thereto; the true Number of Eclipſes may be ſhewn by a Lamp. Or, if the Moon's Orbit be properly inclined to the Ecliptic in an Orrery; ſuppoſing the Moon to be ſcarce $\frac{1}{12}$ of an Inch in Diameter, her Orbit would need to be 15 Inches wide; and the Earth's Diameter about $\frac{1}{4}$ of an Inch: In this Caſe the Magnitudes of the Earth and Moon would bear a juſt Proportion to their Diſtance from one another; and ſo the right Number of Eclipſes would be ſhewn by them.

But knowing this laſt Method to be impracticable in any common Orrery, I took another Way of ſhewing the true Number of Eclipſes in mine; namely that of ſetting their Limits on the Moon's Orb as before mentioned; and this needs no other Earth and Moon than the large ones, whereby the other Problems are ſolved. It being eaſy to conceive how, if theſe Bodies were ſmall enough in Proportion to their Diſtance from one another, the Shadow of either of them might freely paſs by the other without touching it, at its proper Diſtance from the Node.

Page 35.

Cuſps or Horns of the Moon.

The Moon from the third Day to the ſeventh Day of her Age, and from the 22d to the 28th Day thereof, always appears horned; the Poſition of her Cuſps or Points of her Horns being very different at different Times; eſpecially at her riſing and ſetting on the ſame Days of her Age. Sometimes ſhe ſtands, as it were, perpendicular to the Horizon, and at other Times ſhe leans much forward or backward thereto. This is very well accounted for, by the Machine; and may be eaſily underſtood without it, by conſidering that a right Line touching both her Cuſps, is always perpendicular to the Ecliptic; or ſo near thereto, that her moving in an inclined Orb will make no ſenſible Alteration, if we conſider how ſmall an Angle that Inclination ſubtends, as ſeen from the Sun, which is next to nothing. And as all Parts of the Ecliptic, except thoſe about the

Their different Poſitions to the Horizon.

How to find their Inclination, and thereby the Inclination of the Ecliptic, to the Horizon.

Beginning of *Cancer* and *Capricorn*, make different Angles with the Horizon on different Sides of the Meridian, but eſpecially at their riſing and ſetting, on the ſame Day; ſo muſt the Cuſps of the Moon do, becauſe they are always perpendicular to the Ecliptic. Hence, if at any Time that the Moon is viſible when ſhe is horned, a Quadrant be held up with the graduated Side toward the Eye, and as far from the Eye as it can be conveniently held; the Arch between the Plumb Line and the Edge that ſeems to touch the Moon, will ſhew the Inclination of that Part of the Ecliptic in which ſhe then is, to the Horizon at that Time: And the Arch between the Plumb Line and the other Edge of the Quadrant, will ſhew the Inclination of a right Line touching the Moon's Cuſps, to the Horizon at that Time alſo.

Why the Moon ſometimes riſes near the ſame Time with the Sun, and on that Day ſets ſo different from him, and *vice verſa*.

This riſing and ſetting of the Ecliptic accounts for the Moon's riſing ſo near the ſame Time as the Sun does; and ſetting ſo far different from the Time that the Sun ſets (and *vice verſa*) for ſome few Days before or after New Moon. This happens in an Oblique Sphere; and is the more remarkable, as Places are more diſtant from the Equator to the Arctic Circle. At *London* in *June*, the Moon on the 26th Day of her Age, when in her greateſt South Latitude, will riſe only an Hour before the Sun, and yet on the ſame Day ſhe will ſet four Hours before him. But on the ſeventh Day after, or third Day of the next Lunation, ſhe will riſe four Hours after the Sun, and ſet only two Hours after him. This Difference is not confined to any particular Time of the Year, but is general, and will more or leſs happen in ſome Days of every Lunation. For, at *London* in the preſent Year 1747, the Moon being five Days old on the 29th Day of *Auguſt*, will riſe ſix Hours and an half after the Sun riſes, and will ſet only one Hour after the Sun ſets. And thus, on the ſame Day, the Horizon of *London* may make ſo great an Angle with the Paths of the Sun and Moon at their riſing, as will cauſe them to differ more than five or ſix Hours; and ſo ſmall an Angle at their ſetting, as to obſcure them both within the Compaſs of one Hour; and yet the Difference of Amplitude may be the ſame in both Caſes. At other Times, as great Difference

A remarkable Difference.

will happen in the ſetting, and as little in the riſing of the Sun and Moon; according to the Poſition of the Horizon and Earth's Axis to the Planes of the Solar and Lunar Motions.

The Harveſt Moon.

This very naturally leads us to the Knowledge of the Harveſt Moon, ſo much talked of; and ſo little underſtood by many, that ſome make a Doubt of it whether the Full Moon at that Time riſes with leſs Difference than at other Times of the Year. I know that the Author of a Book called, *A Complete Syſtem of Aſtronomy*, therein denies it; reckoning it to be a groſs Abſurdity, talked of only by the Country People. But Experience ſhews that it is a great Truth; and what may be very well ſhewn upon any common Globe, by obſerving how large a Quantity of the Ecliptic about *Aries* always riſes in a ſhort Time, when compared with the like Quantity thereof about any Sign that is 30 or more Degrees diſtant from *Aries*: The plain Reaſon of this is, that the Ecliptic about *Aries* in our oblique Sphere, makes a leſs Angle with the Horizon when it riſes, than any other Sign does therewith; and a greater Angle at ſetting. And conſequently, when the Moon is in that Sign or near to it, ſhe will riſe with leſs Difference of Time, and ſet with more, than in any other Part of the Ecliptic. This will happen in every Lunation, becauſe the Moon goes through all her Signs once every Lunar Month; but ſhe is never Full in *Aries*, except in Harveſt; the Sun being then in the oppoſite Sign *Libra*. And therefore, no Full Moon in the Year will riſe ſo near the ſame Time for ſome Nights together, nor ſet with ſo much Difference in the ſucceeding or following Mornings, as the Harveſt Moon does. Theſe Things are demonſtrable to the meaneſt Capacity, by the plain Orrery here deſcribed; from which all is taken that is mentioned concerning the Phenomena of the Harveſt Moon, at the Beginning of this Book; whereto I refer the Reader: It being needleſs to repeat any more in this Place, of what is mentioned already.

A plain Demonſtration thereof.

All that I ſhall obſerve more upon this Subject, is, that we have had advantageous Harveſt Moons from the Year 1742; and will have them ſo, until the Year 1751: The Full Moon in *September* being always during that

And of its not being always the ſame.

that Time in Aſcending Latitude. But from 1751 till 1760, they will have the Diſadvantage of riſing conſiderably later every following Night; becauſe the Full Moon in *September* during that Time will always be in Deſcending Latitude. Thus they go through a Courſe of moſt and leaſt advantageous, every 19 Years; becauſe in that Time, the Nodes moving backward, go quite round the Ecliptic. But this ſhifting of the Nodes will never affect the Moon's riſing ſo much, even in her quickeſt Deſcending Latitude, as not to allow us the Benefit of her riſing nearer the ſame Time for ſome Nights together in Harveſt, about her Oppoſition to the Sun, than when ſhe is about the ſame, in any other Month of the Year.

To ſhew the Time of riſing and ſetting of the Sun and Moon, at any Place of the Earth.

To ſhew the riſing and ſetting of the Sun and Moon, any Day of the Year, at any given Place on the Earth: Put the Horizon upon the Globe, ſo as it may repreſent the Horizon of the given Place (ſee Pag. 27); then move the Box forward, until the annual Index comes to the given Day in the Circle of Months: Stop there, and ſet the Moon to her Age on that Day, in the Circle of 29 $\frac{1}{2}$ equal Parts: which done, turn the Earth on its Axis, until the graduated Arch comes to the Solar Ray, and then ſet the Hour Index to XII. Laſtly, turn the Earth eaſtward on its Axis, and you'll ſee the Times of the riſing and ſetting of the Sun and Moon pointed out by the Hour Index; with their Amplitudes where they cut the Horizon; and their Altitudes in the Meridian as they paſs over the graduated Arch abovementioned.

At the Equator.

At the Equator, the Sun and Moon will be every Day as long above, as below the Horizon; the Sun always riſing at 6 in the Morning, and ſetting at 6 in the Evening; the Moon being about 50 Minutes later in riſing every Day or Night than on the preceding, and as much in ſetting; ſo that ſhe is always much about 12 Hours and 25 Minutes above, and as long under the Horizon. And for this Reaſon there is no Harveſt Moon at the Equator; nor is there any need for it, becauſe there is no Difference of Seaſons.

At the Tropics.

At the Tropics, the Seaſons vary a little; the Sun being 47 Degrees from the Vertex of the one, when he touches that of the other. In Summer he will riſe a Quarter paſt Five in the Morning, and ſet three Quarters paſt Six in the Evening: And in Winter, he will riſe a Quarter before Seven, and ſet a Quarter after Five; the longeſt Day containing only 3 Hours more than the ſhorteſt. Here the Moon is not ſo equable in her riſing and ſetting, as at the Equator; for in Winter, at her Full, ſhe continues as long above the Horizon as the Sun does in Summer; and *vice verſa.* The Harveſt Moon begins to be ſenſibly different; for *Aries* riſes in the Eaſt, at an Angle of 43 Degrees with the Horizon; whereas in the Weſt he ſets perpendicularly, or at Right Angles with it.

At the Polar Circles.

At the Polar Circles, when the Sun touches the Summer Tropic, he will, on that Day, continue all the 24 Hours above the Horizon, without ſetting; and when he touches the Winter Tropic, he will continue 24 Hours below the Horizon, without riſing. Conſequently, the Full Moon (being always in the oppoſite Sign to the Sun) riſes not in Summer, and ſets not in Winter. A wonderful Inſtance of the Wiſdom and Goodneſs of the Almighty! in cauſing Nature to hold us out a Lamp from Heaven, to ſupply us with Light in the long Winter Nights. The Winter Full Moons being as high as the Sun is in Summer, muſt therefore continue as long above the Horizon; it being moſt needful that they ſhould do ſo. And as in Summer the Days are long, and Nights ſhort, ſo the Full Moons in Summer are always low, and their Stay ſhorteſt above the Horizon, when we have leaſt Occaſion for Moon Light. Here the Harveſt Moon, from the firſt to the third Quarter, or for 15 Days, when ſhe gives moſt Light, will riſe within the Compaſs of an Hour, as beforementioned. *See Pag.* 8.

At the Poles.

At the Poles, the Sun continues half a Year above the Horizon, without ſetting, and as long below it without riſing; conſequently, they have all Day and no Night in Summer; and all Night and no Day in Winter: For, at the North Pole, the Sun riſes when he enters *Aries*, and ſets when he enters *Libra*; and *vice verſa* at the South Pole. Here 'tis remarkable, that the Poles never ſee the Full Moon in Summer; becauſe the Moon ſets at her firſt Quarter, and riſes not until her third. But in Winter, they have the Full Moon conſtantly ſhining upon them; for ſhe riſes at her firſt Quarter, and keeps conſtantly above the Horizon, without ſetting, until her third

Quarter; or for a Quantity of Time equal to 15 Natural Days. Thus they are ſupplied for one Half of the Winter-time with Moon Light, when the Sun is ſo long abſent from them: And their Moon Light is at the Time when the Moon is capable of giving the moſt. In Spring, the Moon riſes at the Change, and ſets at the Full; and in Autumn, ſhe riſes at the Full, and ſets at the Change.

Theſe Phænomena of the Moon are only what would happen, if ſhe moved always in the Ecliptic: As for the Difference on account of her inclined Orbit, that can be better underſtood by ſeeing a little of her Motion on the Orrery, than by a long Deſcription here.

Præceſſion of the Equinoxes. The Earth's Axis varies a Degree every 72 Years from its Parallelisſm, weſtward; and ſo much will the Equinoctial and Solſtitial Points recede in that Time, from the Conſequent toward the Antecedent Signs: which is the Reaſon of that ſlow apparent Motion of the fixed Stars the contrary Way, or according to the Order of the Signs. This will cauſe the Seaſons to go once backward, thro' all the Days of the Year, in 25920 Years. Therefore, if the Earth ſhould laſt half that Time from the preſent Year 1747, or 12960 Years, the tenth of *December* would then be the longeſt Day in the Year, the tenth of *June* the ſhorteſt, the vernal Equinox would fall on the twelfth of *September*, and the autumnal Equinox on the ninth of *March*, in the Northern Hemiſphere; and the contrary, in the Southern.

This, tho' an uncommon Problem, is ſhewn as plainly as any other, by this Orrery: But I have made it ſo, as the Equinoxes recede much quicker in it than they do in Nature; only becauſe if they had no quicker Receſſion, I know not who would have Patience to turn the Earth round the Sun a Number of Times ſufficient to ſhew it. Therefore,

How ſhewn by the Orrery. Rectify the Machine, and move the Box till the annual Index comes to the ninth of *March*, whereon the vernal Equinox happens in the preſent Age. Then turn the Earth on its Axis, until the graduated Arch comes to the Solar Ray, which will ſtand over the Equator, pointing to Æ, or no Declination. This done, bring the Earth about 20 or 30 Times round the Sun, and then ſtop at the ninth of *March*, whence you ſet out: In which Time the Earth's Axis will have changed its Parallelifm a little Weſtward; and the Solar Ray will point a little Northward of the Equator; ſhewing that the Sun has got ſome North Declination on the graduated Arch. And if you move the Box a little backward, till the Ray points to the Equator again, you'll ſee the annual Index point to the 7th or 8th Day of *March*. N. B. *Always after ſhewing this Problem, the Machine muſt be again rectified.*

If the Earth had no Motion round its own Axis, it would ſhew itſelf all round to the Sun once every Year: in which Time, its Axis ſtill inclining the ſame Way, all Parts of it would have one Day and one Night. This is demonſtrable by the Machine, which does not at all turn the Earth on its Axis; and therefore it ſhews itſelf all round to the Sun, in going once round about him. But, if while with one Hand you bring the Earth once round about the Sun, you turn it the ſame Way round its Axis with the other; it will then keep always one Side toward the Sun, having continual Day on that Side, and continual Night on the other. If while you carry the Earth once round about the Sun, you turn it the ſame Way twice round its Axis, it will ſhew itſelf all round to the Sun once in the Time that it goes round about him: If three Times, it will ſhew itſelf twice, &c. Thus, if the Earth turned twice round its Axis in one annual Progreſs round the Sun; it would have the ſame Effect with regard to Day and Night, as if it did not at all turn round any Axis within itſelf. But with regard to Sydereal Time, it would be quite otherwiſe: For if it did not turn, the Sydereal Time would ſtill be the ſame: and if it turned twice, there would be two Sydereal Days in the Year. Hence, becauſe the Moon ſtill keeps the ſame Side to the Earth, and goes round about the Earth, as the Earth does about the Sun, ſhe turns once round her own Axis in the ſame Time that ſhe goes once about the Earth.

A Proof of the Moon's turning round her own Axis.

If the Moon had no Motion at all, either round the Earth, or her own Axis, but was ſtationed between the Earth and any fixed Star in the Ecliptic; ſhe would, in accompanying the Earth about the Sun, ſhew herſelf all round to him in a Year, and compleat juſt one Lunation in that Time; changing all her Phaſes once to the

Earth, and keeping ſtill the ſame Side toward it. Thi is ſhewn by taking the Moon from her Socket in the Machine, and ſticking her Axis in her Orbit; and then i moving the Earth once round the Sun, you'll ſee juſt one Lunation performed. This is eaſily underſtood, by conſidering that the Moon's Orbit, as to its Signs, has no Motion round an Axis within itſelf; becauſe the ſame Signs of it always look toward the ſame Signs of the Ecliptic, which is at reſt.

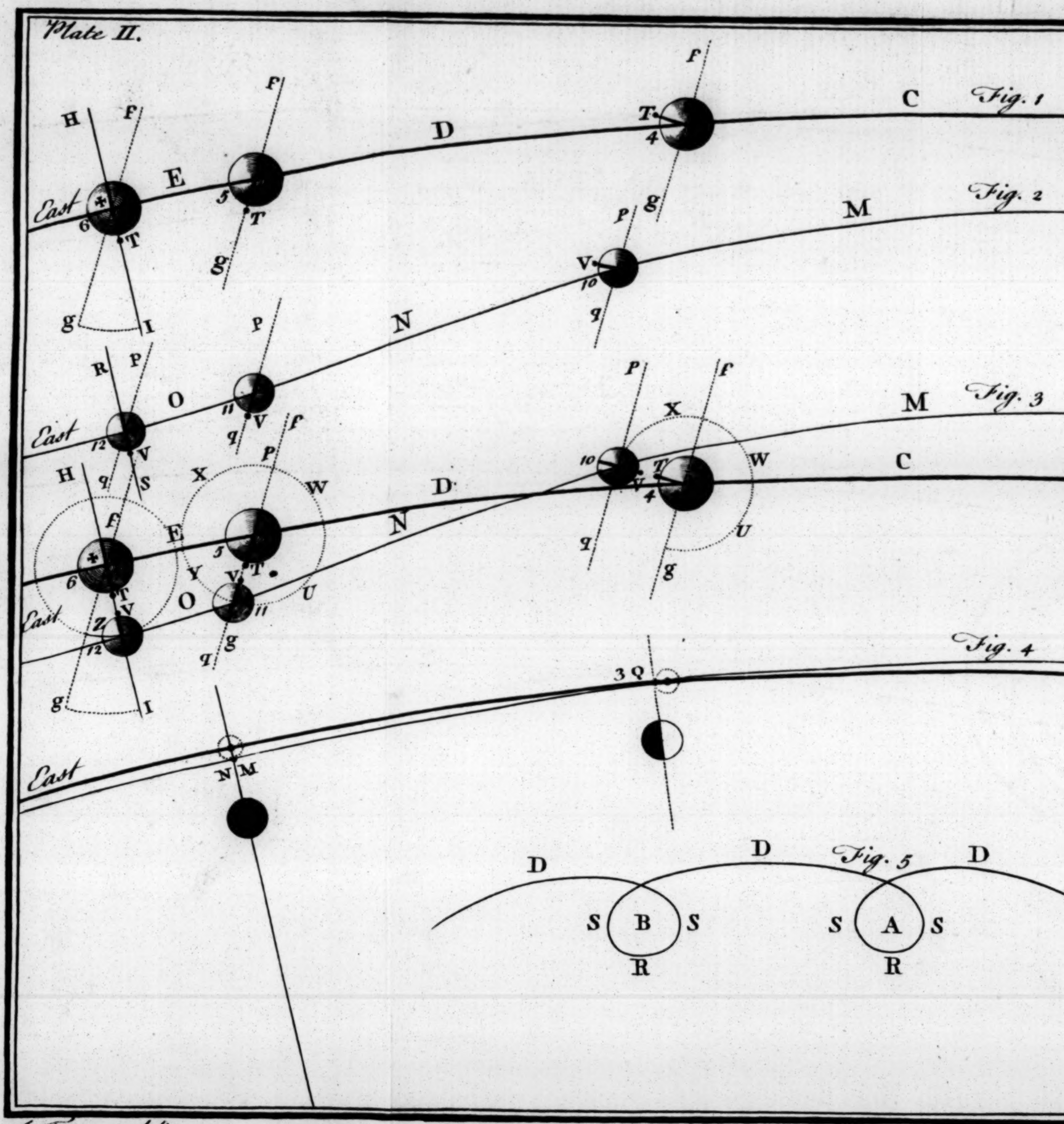
So much for a Deſcription of this plain Orrery, which has only four Wheels, without either a Pinion, or Screw, to cauſe it ſhew all the abovementioned Phænomena. Hence we may ſee how eaſily a Machine can be made, which may ſolve as uſeful Problems, and more in Number, than what are performed in the Way that Orreries are commonly made; eſpecially ſuch as take in all the Planets; where a Multiplicity of Wheels muſt be had, to carry them round in ſuch a crowded Manner, as renders it impoſſible to ſhew all the uſeful Effects of the Motions of our own Earth and Moon, although theſe are what moſt nearly concern us.

It may be objected, that this Machine ſhews not the Earth's diurnal Motion, tho' that be more beneficial to us than all the reſt. But in Anſwer to this, I ſay, that both Motions may be carried on together, by two Perſons, at Pleaſure. For, if a Thread be wrapped round the Earth's Axis a great many Times, let one hold the End of the Thread in his Hand, while another moves the Box with the Earth about the Sun; and the Earth will then turn round its Axis, while it is carried forward in its progreſſive Motion. Or, either of the Motions may be carried on without the other; to ſhew what would have been the Conſequence of either without the other.

In this Paper, I have had frequent Occaſion to mention the Moon's turning round her Axis; which Motion has been denied her in former Times, and is ſo ſtill, by very ingenious Gentlemen, well ſkilled in the Mathematical and Aſtronomical Sciences. I therefore reckon myſelf bound to defend what I have ſaid on that Subject, in the beſt Manner I can: And this I ſhall endeavour to do in the following Paper.

A N

Plate II.



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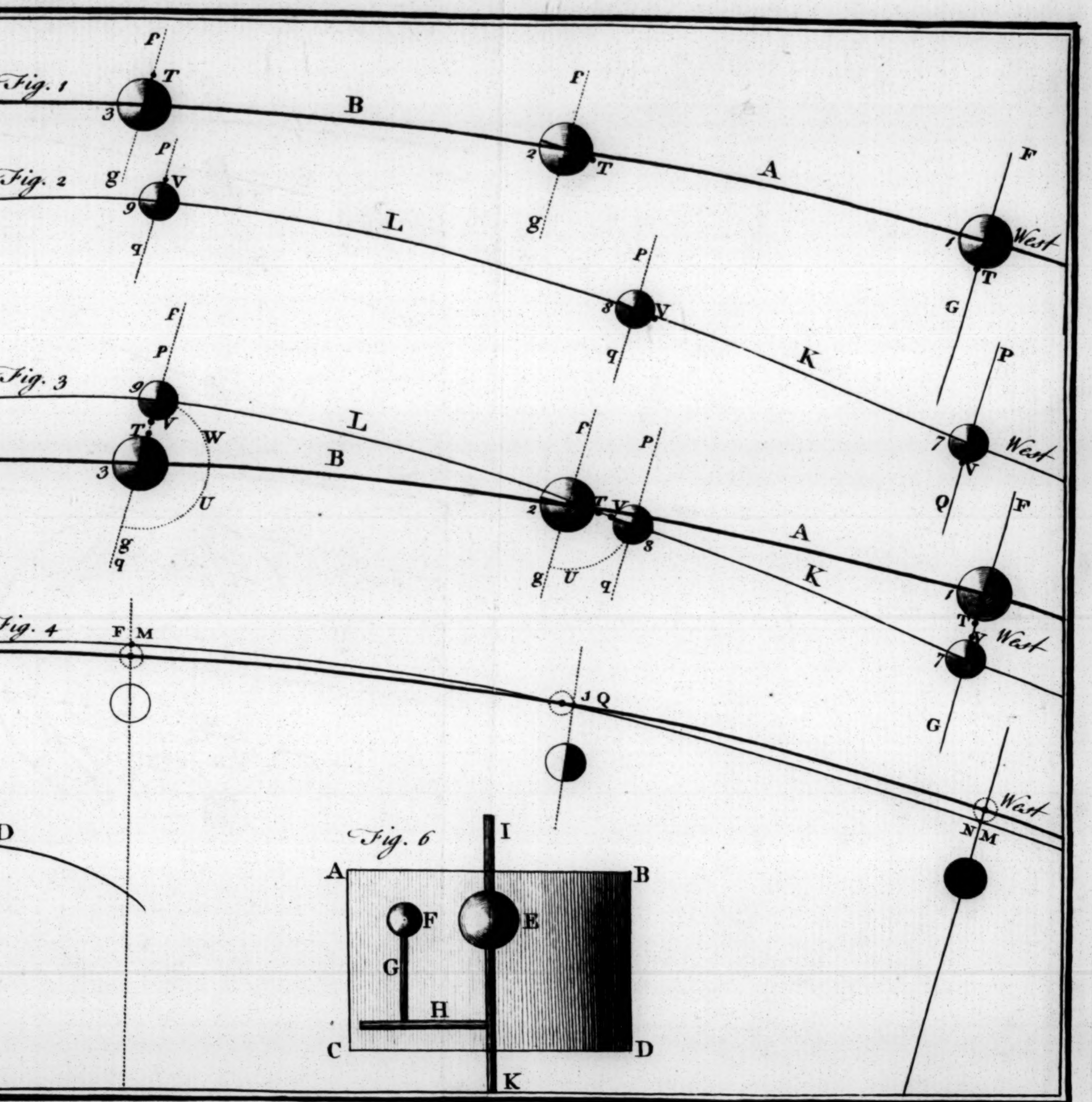

G. Child Sculp.

AN ESSAY ON THE

MOON's turning round her own AXIS.

NOthing can be more plain than that it is loſt Time which is taken up in defending ſelf-evident Axioms, or in proving unconteſted Truths. But altho' I may venture to ſay, that Ninety and Nine Perſons of every Hundred, who know any thing of Aſtronomy, are ſo well ſatisfied as to the Truth of the Moon's turning round an Axis within her own Body, exactly in the Time of her going round the Earth, that they conſider it as a ſelf-evident Axiom: and that her keeping ſtill the ſame Side towards the Earth is the neceſſary Conſequence of her turning round her own Axis: yet, ſuppoſing that there was One in every Hundred well ſkill'd in the Aſtronomical Science, who made a Doubt of it, or ſtrongly denied it; there would be a great many whom it would be the Duty of others to convince, or at leaſt endeavour to do ſo. And to this Duty, every one may claim a Right, who has ſtudied the Effects of ſimple and complicated Motions; although he ſhould be no Aſtronomer.

They who deny the Moon's turning round her Axis, lay it down as a fundamental Criterion, "That a progreſ-
" ſive Body, which keeps conſtantly all its Diameters and
" Parts in the ſame Poſition with regard to the Line of its
" Progreſs, does not turn on an Axis within itſelf; and
" there-

" thereby, in a circular Progreſs, keeps always the ſame
" Side to the Center of its Orbit. And *vice verſa*, if a
" Body in its Progreſs continues varying the Poſition of
" its Diameters and Parts to its progreſſive Line, it does
" turn on an Axis within itſelf; and muſt ſhew itſelf all
" round to the Center of its Orbit."

The Argument is not whether a Body turning round its Axis, be fixed thereon, as a Wheel in a Clock; or looſe thereon, as a Wheel of a Chariot; in the firſt of which Caſes, the Wheel turns its Axis round with it; and in the laſt, it does not: But whether or not it turns round a mathematical Line within itſelf; which is the Axis here meant. For every one knows, that the Moon has no material Axis, ſuch as our common Globes have, to turn upon.

As to the firſt Part of the Criterion, 'tis certain, that if the progreſſive Motion be in a ſtraight Line, the Body keeping all its Diameters in the ſame State to the Line of its Progreſs, does not turn round its own Axis. But in every other Caſe, the moving Body will vary the Poſition of its Diameters from their Paralleliſm in open Space, according to the Line in which it is moved. Thus, ſuppoſing the progreſſive Line to be on the Floor of a Room, in a Curve returning into itſelf, as a Circle, Ellipſis, &c. the Diameters (which by the Suppoſition keep always the ſame Poſition to that Line) in one Revolution of the moving Body, will have varied their Poſitions quite round to all the fixed Points of the Horizon; that is, the Body itſelf muſt have made one compleat Revolution round its Axis.

If the Line of progreſſive Motion was compounded of ſeveral ſtraight Lines joined together at different Angles; ſo far as the Line is ſtraight, ſo far the moving Body will keep the ſame abſolute Poſition of its Diameters. But at each Angle of the Line of Motion, as the Direction of that Line changes, the Diameters of the moving Body, which retain the ſame Poſition to that Line, muſt change their Direction with it. A Man ſitting ſtill in a Ship, if he keeps always his relative Situation in it, will, notwithſtanding, be carried along with the Motion of the Ship; and if the Ship turns round, he turns round with it. And with regard to the abſolute Motion of his Body, he as much turns round, as if, independent of the Ship, he had turned himſelf, or been turned by any other Cauſe. His conſtantly looking toward the ſame Part of the Ship, is ſo far from being an Argument of his not turning, that it plainly evinces the contrary. For two Bodies, one whereof moves, and the other is at Reſt, cannot poſſibly keep the ſame Situation to one another. On the contrary, if the Man in the Ship was to turn himſelf round with the ſame Velocity as the Ship turned, but the contrary Way, he would, in that Time, have turned his Face ſucceſſively towards all the Parts of the Ship, and yet, in Point of abſolute Motion, have kept the ſame Situation as he had before; and the Ship would have turned round him as a fixed Axis. Or if he had turned himſelf round with double the Velocity of the Ship, and the ſame Way that the Ship turned, he would have ſhewn himſelf all round to the Ship but once; and yet have abſolutely turned twice round his own Axis.

Over the Center of a Table, hang a Ball by a Piece of twiſted Packthread; which untwiſting itſelf, will turn the Ball round pretty quick at firſt, but gradually ſlower and ſlower, till it has untwiſted itſelf, and ſo leaves off turning. Twiſt it again, and holding the upper End of the Packthread ſteady in your Hand, cauſe the ſuſpended Ball to perform circular Vibrations round another Ball at reſt on the Table, making it circulate the ſame Way that the Thread untwiſts. At firſt, in every Vibration it will ſhew itſelf all round ſeveral Times to the central Ball, as it often turns round its Axis. But watch its Motions, as it turns round ſlower and ſlower in every circular Vibration, and you'll ſoon ſee it keep the ſame Side toward the central Ball, during one or two of its circular Vibrations round the ſame. Shall we then ſay, that the circulating Ball has juſt left off turning round its own Axis? No certainly; for if you pull your Hand a little to one Side, you can ſtop the circular, without touching the Ball, or affecting the central Motion; and will yet ſee the Packthread ſtill untwiſting itſelf, and the Ball turning round its Axis the ſame Way as at firſt ſetting out. This demonſtrates, that a progreſſive Body may, or may not, ſhew itſelf all round to the Center of its Orbit, and yet turn round an Axis within itſelf. In making this Experiment, the Ball ſhould be at leaſt three Inches Diameter.

Hang a Ball over the Table, as above; only inſtead of Packthread, uſe a String, or broad Piece of Tape, that will not twiſt eaſily; fixing the upper End of the Tape to the Cieling of a Room, ſo that it cannot turn round. Then, with your Hand, carry the ſuſpended Ball round a Ball at reſt on the Table, making it always keep the ſame Side thereto; and in carrying it round once, you'll ſee it will twiſt the Tape once; if twice, it will twiſt it twice, and ſo on; which proves that the circulating Ball, by twiſting the Tape, turns round its Axis, and keeps all its Diameters in the ſame Poſition to the Line of its circular Progreſs.

As to the ſecond Part of the Criterion, *viz.* "That "if a Body in its circular Progreſs conſtantly changes the "Poſition of its Diameters to its progreſſive Line, it does "turn on an Axis within itſelf, and muſt ſhew itſelf all "round to the Center of its Orbit." This is not univerſally true; for, if you make the abovementioned Ball perform circular Vibrations round a Ball at reſt on the Table, without twiſting the Tape, it will conſtantly vary the Poſition of its Diameters to the Line of its Progreſs, and in every Revolution it will ſhew itſelf all round to the quieſcent Ball in the middle of its Orbit, without turning round its own Axis; as it twiſts not the Table, which is fixed both to it, and to the Cieling of the Room.

While a Watch hangs perpendicularly by her own Gravity, upon a Nail or Knob, or any Thing whatſoever, ſhe cannot turn round her own Axis, without either twiſting her String, or wrapping herſelf up in it. Now, inſtead of a String (or any Thing flexible) I will ſuppoſe her to be hung by a wooden Bar, about two Foot long; near the upper End whereof, there is a Hole for hanging her on a Knob; and round the Hole two concentric Circles, for inſcribing the twelve Hours, as on the Dial Plate. Fix one Spring Clock, that has only an Hour Hand, without a Minute Hand, directly over another; making the Diſtance between the Centers of their Dial Plates, equal to the Diſtance of the Center of the Watch from the Middle of the ſaid Hole, in the Bar that hangs her: And fix a Knob into the End of the Hand that indicates the Hours upon the uppermoſt Clock. Then, hang the Bar on this Knob; and as the Hour Hand goes round, on the uppermoſt Clock's Dial Plate, the Knob thereon will carry the Watch (which always hangs perpendicularly by the Bar) quite round the Hour Circle, or Dial Plate, of the lowermoſt Clock. And the Watch, which ſtill hangs perpendicularly, will, in one Revolution, ſhew herſelf all round to the Center of the Orbit ſhe deſcribes; which is the Center of the lowermoſt Clock's Dial Plate. The Knob on the uppermoſt Index, being fix'd into it, keeps ſtill the ſame Side to the Center of its Orbit; and yet, it will evidently appear that the Knob turns round an Axis within itſelf, juſt as much as the Hour Hand does, whereon it is fixed. For, if an Index be fixed on the End of the Knob that comes through the Bar, that Index will turn round the Dial Plate on the Bar; and will point out all the Hours as regularly thereon, as the Index of the Clock whereon it is fixed, does on the Dial Plate of the Clock itſelf. And all the Indexes will conſtantly keep parallel to each other.

When I ſit ſtill at my Writing Table, I often (as it happens in Courſe) make a Capital O, or a Number of ſmall Cyphers: and will any one tell me, that in every one of theſe, I turn the Pen once round its Axis; becauſe, by keeping it ſteady in my Hand, I make its Point ſhew itſelf quite round to the Center of every ſuch Orbit that it deſcribes? I own, that if I ſhould twirl the Pen round betwixt my Fingers and Thumb, for every ſuch O, or Cypher, I would indeed turn the Pin round an Axis within itſelf; but then, it would ſtill ſhew the ſame Side of its Point to the Centre of its Orbit; and I would find this a very ſlow and troubleſome way of writing. Or, if I keep the Pen ſteady without twirling, while I make ſuch a Letter or Cypher, and yet, all the Time, cauſe the Pen to keep the ſame Side towards the Middle thereof; I muſt riſe, and walk round the Table: by which Means, I as plainly turn the Pen round, as a moving Wheel fixt upon its Axis, turns the ſame round with it.

From

From this Criterion, an Objection againſt the Moon's turning round her Axis, may very naturally ariſe in the following Manner. The Number of Days in a Year is equal to the Number of Turns that the Earth makes on its Axis, in the Time of its going once round the Sun, which is 365 $\frac{1}{4}$: becauſe, nothing but the Earth's turning on its Axis, occaſions the alternate Returns of Days and Nights. Theſe, if the Creator had pleaſed, might have been more than 365; or any leſſer Number down to one. And ſo, if there had been but one Day in a Year, the Earth would have turned but once round its Axis in that Time. Now, ſince the Moon goes round the Earth, as the Earth does round the Sun; if while ſhe goes once round the Earth, ſhe turns once round her Axis, ſhe would ſhew herſelf all round to the Earth, as it would ſhew itſelf all round to the Sun; without which, a Natural Day (containing both a Day and a Night) could not be produced.

I never heard this Objection made by any, whom I had not the good Fortune to convince, that it was grounded upon a wrong Suppoſition; by not conſidering the Difference between a Body's turning round its Axis, while it moved in a Circular or Elliptical Progreſs, and of its turning round its Axis in any Part of the Periphery of the Circle or Ellipſe, without a progreſſive Motion. For, in the firſt Caſe, an abſolute Turn of the Body round its Axis, will never make it ſhew itſelf all round to the Center of the Orbit; and in the laſt Caſe, it always will.

This brings me to what I mentioned before *, concerning the Solar and Sydereal Time; or the Earth's turning itſelf quite round to the Sun, and to any given fixt Star; in which there is always a Difference. For, becauſe of the immenſe Diſtance of the fixt Stars from the Earth, to which, the whole Diameter of its Orbit, tho' 162,000,000 of Miles long, is but a Point in Compariſon; therefore, right Lines drawn from all Parts of the Earth's Orbit to any given fixt Star, are phyſically Parallel. And conſequently, an abſolute Turn of the Earth round its Axis is compleated, when the Plane of any Meridian-Semicircle has revolved quite round, ſo as to paſs thro' the ſame fixt Star from whence it ſet out. This is called a Sydereal

* Pag. 27.

Day; and is performed in 23 Hours and about 56 Minutes of mean Solar Time. But Lines drawn from al Parts of the Earth's Orbit, to the Sun in the Center thereof, are ſo far from being parallel to one another, that they may be compared, in a great Meaſure, to the Arms or Spokes of a Chariot-Wheel; which, the further they go from the Nave toward the Rim, the further they ſeparate. Now, let us ſuppoſe the Earth's annual Orbit to be a great fixt Wheel, of 365 Spokes, equally ſet from the Rim to the Sun, or Nave thereof; each of theſe Spokes will be almoſt a Degree diſtant from the other: And the Earth, in its annual Motion, advancing every Day a Spoke forward along the Rim of the Wheel; we will immediately be convinced, that the Earth muſt neceſſarily turn almoſt a Degree, or, ſtrictly ſpeaking, $\frac{1}{365}$ Part more than once round its Axis, to exhibit a Natural or Solar Day: becauſe in that Time, any Meridian-Semicircle revolving round from the Sun to the Sun again, muſt paſs from the ſame fixt Star whence it ſets out at the ſame Time as it does from the Sun's Centre, to the ſame fixt Star again, and as much more as it has advanced in its annual Progreſs for that Time; or $\frac{1}{365}$ Part of a Circle, before it comes to the Sun's Center again.

Hence 'tis plain, that $\frac{1}{365}$ Part of a Turn, added to every Day, will make up a compleat Turn in 365 Days, more than the Number of Days in our Year. And conſequently, if the Year contained but one Natural Day, and the Earth turn'd round its Axis the ſame Way as it goes round the Sun, it muſt in that Time turn twice round its Axis, to produce that one Natural Day: One abſolute Turn of the Earth round its Axis, with regard to Day and Night, being loſt every Year; as it would be loſt to a Traveller if he would go round the Earth from Eaſt to Weſt, following the apparent diurnal Motion of the Sun. For, let him take what Time he will in going round, yet, when he returns, he will, by having kept an exact Account, reckon one entire Natural Day leſs than they who ſtaid at the Place from whence he ſet out.

'Tis very true, that if the Almighty had pleaſed, he could have made the Year to contain more than 365 Days, or any leſs Number, down to One. But then, one Turn of the Earth on its Axis would have been ſo far from producing *that* Day, that inſtead thereof (by what is ſaid above) 'tis evident, that one Side of the Earth would have always kept toward the Sun; and ſo there would have been perpetual Day on that Side, and perpetual Night on the other.

If the Number of Days in a Year were ſmall, the Difference between the Sydereal and Solar Days would be ſo much the greater in Proportion, than if it contained many Days. On our Earth, the Difference is ſcarce four Minutes, which is too ſmall to be repreſented in a Figure: And therefore, to ſhew it the better, I ſhall ſuppoſe the Year to contain ſome ſmall Number of Days; as for Example, Twelve; which will make the Difference between the Sydereal and Solar Day very plain. For,

Plate II. Fig. 1. Let the Curve ABCDE repreſent a twelfth Part of the Earth's annual Orbit, bounded by the Right Lines FG and HI, which continued on ſtraight from G and I, would meet in the Center of the Curve, or in the Sun. And let the Center of the Earth T deſcribe this Curve in a Solar Day; in which Time, its Diameter, with the Dott upon one End, at T, will have gone round its Axis from the Sun to the Sun again; and will alſo have made all poſſible Angles with the Line of its Progreſs. From the Line FG, let another Line, as fg, be carried parallel thereto, along the Curve, with the ſame Velocity that the Earth proceeds from Weſt to Eaſt; by which Means, fg keeping always parallel to itſelf, will conſtantly point to the ſame fixt Star that FG does; and ſo will meaſure the Parts of the Earth's diurnal Motion. At 1, the Dott T on the Earth points toward the Sun, becauſe it is in the Right Line FG; which, if produced, would connect the Sun and Earth. But when the Earth, in its progreſſive Motion, arrives at 2, the Diameter with the Dott has turned to T, at Right Angles to the Line fg; and conſequently, the Earth has made a Quarter of a Turn on its Axis. At 3, it has turned half round, being got into the Line fg, toward its uppermoſt End. At 4, it has turned three quarters round; the ſaid Diameter being again at Right Angles to the Line fg, but the Dott on the contrary Side to which it was at 2. At 5, it has

turned abſolutely once round its Axis, becauſe the Dott has revolved quite round to the Line f g; and ſo the Diameter T at 5, being parallel to the Poſition that it had at 1 in F G, muſt now point again to the ſame fixt Star; and ſo have finiſhed its Sydereal Day. But the ſaid Diameter does not yet look toward the Center of the Curve, in which the Earth has gone from 1 to 5; and therefore it muſt go a little further, as from 5 to 6; in which Time, the Earth, by continuing its diurnal Rotation, will have turned the Dott on the foreſaid Diameter directly toward the Sun; for it will lye in the Right Line H I, which continued inward, would go to the Sun in the Center of the Earth's annual Path; and here, the Solar Day is finiſhed; which is as much longer than the Sydereal, as the Diameter T is in revolving from f g to H I, on the ſame Side; or equal to the Angle g + I: which may be converted into Time, by the following Analogy. As 360 Degrees is to the Length of a Sydereal Day, ſo is the Angle g + I to a fourth Number; which muſt be added to the Sydereal Day, to compleat the Solar Day; or the Earth's turning the ſame Semicircle round its Axis from the Sun to the Sun again. Theſe different Angles added together for a whole Year, will make juſt 360 Degrees; which is one abſolute Turn of the Earth round its Axis, or one Sydereal Day more than the Number of Solar Days in the Year.

If the progreſſive Motion of a Globe be unequal, and in an irregular Curve, that will not hinder the Globe from turning equally or uniformly round its Axis; the diurnal and annual Motions being quite independent of one another. For, ſuppoſe the Globe V takes as much Time in deſcribing the ſhorter Space from 7 to 8, in the irregular Curve K L M N O, as in deſcribing the longer Space from 8 to 9; in theſe equal Times it will make equal Parts of a Revolution on its Axis: As is ſeen by the Diameter V, which at 8 croſſes the Line p q (which in this Figure keeps always parallel to P Q, as in the other Figure f g does to F G) at right Angles; and at 9, it lyes in p q, diametrically oppoſite to where it lay in P Q, at ſetting out from 7; having now turned half round its Axis. At 10 it has got three Quarters Fig. 2.

round;

ound; and at 11 it has turned quite round, becauſe then the Diameter V is become parallel to the Poſition it had at 7, in the Line P Q; and ſo has finiſhed its Sydereal Day: And will compleat its Solar Day, when at 12 the ſaid Diameter lyes in the Line R S, which points toward the Sun, as P Q does.

Here it is very plain, that both theſe Globes T and V have, with their foreſaid Diameters, formed all poſſible Angles with the Lines of their progreſſive Motions, as they have been turning round their reſpective Axes. And it is likewiſe plain, that if the Curves were drawn out ſo as to return into themſelves; each Body going round as above deſcribed, would abſolutely turn once more round its own Axis, than any given Diameter or Semi-circle thereon would form all poſſible Angles with the Line of its Progreſs, in going once round the ſame. Therefore, if a progreſſive Body ſhould never vary the Poſition of its Diameters to the Line of its circular or elliptical Progreſs, it would turn once round its Axis in deſcribing the ſaid Line.

And this leads me very naturally to ſhew, that the Moon's Motion round the Earth, or her Track in open Space, is ſo far from being like that of one Ball's going round another at reſt on a Table, as not to bear any Reſemblance thereto. For, the Track of the moving Ball is ſuppoſed to be either circular or elliptical. But if we could trace the Moon's real Path in the Heavens, it would be ſo far from reſembling either a Circle or Ellipſis, that it would be ſomewhat like the Line deſcribed by a Nail in the Rim of a Chariot Wheel, as it is driven over a Piece of Ground whoſe Surface reſembles a Segment of a Circle. And though the Nail moves circularly round the Center of the Wheel, yet that is only a relative Circle; to which, the Line of its abſolute Path would have no Likeneſs: And in this Manner, I am to conſider the Moon's abſolute from her relative Motion.

Join the firſt and ſecond Figures together, and they will make up the third Figure; which ſuppoſes the Year to contain juſt 12 natural Days, and as many compleat Lunations; making always a Solar or Natural Day, and a

Synodical Revolution of the Moon, equally long; and both to turn round their own Axis in the ſame Time; which the Objectors allow might have been the Caſe. And then, not only the ſame Side of the Moon would have conſtantly kept toward the Earth, but likewiſe, the ſame Side of the Earth would have conſtantly kept toward the Moon; and although both of them turned round their reſpective Axes, yet either of them being viewed from the other, would not appear to have any ſuch Motion; becauſe, in ſome Meaſure, they would reſemble two Men ſitting ſtill in a Ship, facing one another; either not appearing to the other to turn round, let the Ship turn round ever ſo often, and they with her; while the Ship and they together have a progreſſive Motion. Now, the Figures being joined,

The regular Curve A B C D E repreſents a twelfth Part of the Earth's annual Path, and the irregular Curve K L M N O repreſents as much of the Moon's, or the Line of her abſolute Motion, for a compleat Lunation. T repreſents the Earth, and V the Moon; each moving from Weſt to Eaſt in its own Path. The abovementioned Dotts being once turned toward one another, will always keep ſo, as in the Figure; and by the Diameter-Lines, on whoſe Ends the Dotts are, the Motion of each Globe round its own Axe is ſhewn. And although the ſaid Diameters conſtantly vary their Poſitions to the Lines of their abſolute Progreſs; yet that Diameter of the Moon (though ſuppoſed to be an equatoreal one) never changes its Poſition with regard to her relative Motion about the Earth; becauſe, as the Figure ſhews, it ſtill keeps perpendicular thereto. For

Fig. 3.

Let us ſuppoſe the Earth T at 1, and the Moon V at 7, juſt ſetting out from a Conjunction in the Line F G, which points toward the Center of the Earth's Curve, where the Sun is ſuppos'd to be placed: The Dott on the Earth and on the Moon being at that Inſtant in the ſaid Line; to which the Lines f g and p q always keep parallel. When the Earth has got to 2, the Moon will be at 8; each having made a quarter of a Turn on its own Axis, as ſhewn by their dotted Diameters, which now ſtand at right Angles to the Lines f g and p q.

The Moon has abſolutely moved in the Curve K, from 7 to 8, but as ſeen from the Earth, or relatively to it, ſhe has deſcribed the Quadrant U, or a fourth Part of her Orbit; to the Center whereof ſhe appears plainly by the Dott, to have kept the ſame Side; but, the Diameter which at her Conjunction was at right Angles to the Line of her abſolute Progreſs, now lyes in it. When the Earth has got to 3, the Moon will be at 9; each having turned half round its Axis, as ſhewn by their ſaid Diameters lying in the Line f g, which now coincides with p q. The Earth has deſcribed the Curve A B, from 1 to 3; and the Moon the Curve K L, from 7 to 9; in which Time ſhe has gone half round the Earth, in the relative Semi-circle U W; or half round her Axis and half round her Orbit. When the Earth comes to 4, the Moon will be at 10; each having made three quarters of a Turn on its own Axis, yet ſtill keep the ſame Sides to one another. As the Earth has gone from 1 to 4, along the Curve A B C, ſo the Moon has gone from 7 to 10, along the Curve K L M; and with Regard to the Earth, ſhe has gone through three Quarters of her relative Orbit, as U W X; to the Center whereof, ſhe has ſtill kept the ſame dotted Side. When the Earth comes to 5, the Moon will be at 11; each having turned quite round its own Axis, as appears by their particular Dotts; which ſtill facing one another, now lye in the Line f g, as it again concides with p q; parallel to F G from whence they ſet out. And here, each finiſhes its Sydereal Day: The Earth having travelled from 1 to 5, along the Curve A B C D; and the Moon from 7 to 11, along the Curve K L M N; in which Time, ſhe has gone quite round the Earth, through all the four Quadrants of her relative Orbit U W X Y. But ſhe has not yet arrived at her next Conjunction; only ſhe has finiſhed her periodical Revolution. And as the Earth goes along E, from 5 to 6; the Moon goes along O, from 11 to 12; when, by turning proportionably on their reſpective Axes, as above, they will now have ſhewn themſelves all round to the Sun; and the foreſaid Diameters of each will have made all poſſible Angles with the Line of its abſolute Progreſs. Yet the ſame Sides have ſtill kept to one another, and the Solar Day to each is compleated. The Moon here finiſhes her Synodical Revolution, being in the Line of Conjunction H I; and has gone $\frac{1}{12}$ Part more than once round her Orbit, or a whole Sign; for ſhe has gone twice over the Arch Z therein, ſince her ſetting out from her laſt Conjunction at 7, in the Line F G.

And now, ſuppoſing it could be demonſtrated, that a progreſſive Body moving either in a Circle or Ellipſis, does not turn round any Axis within itſelf, if it ſtill keeps its Diameters in the ſame Poſition with regard to the Line of its Progreſs: Yet that could make nothing againſt the Moon's turning round her own Axis; ſince it is demonſtrable by this Scheme, that let one pitch upon what Diameter of her he pleaſes, except her Axis, it will make all poſſible Angles with the Line of her Progreſs in the Heavens; and does ſo, twelve Times in every Year.

The only Thing wherein this Figure differs from a true Reſemblance of the Moon's Path in the Heavens, is, that the Curve in which ſhe really moves, comes nearer to the Appearance of a Circle, than here repreſented. But that can make nothing againſt my preſent Demonſtration; for the nearer Reſemblance that the Moon's Path bears to the Earth's *, ſo much the eaſier does it help to conceive her turning round her own Axis in the ſame Manner, though not ſo quick, as the Earth turns round its own Axis. And I had no other Reaſon here for repreſenting the Earth's diurnal Motion to be ſo ſlow, than only to ſhew, that if the Earth's diurnal Motion had been equal to the Moon's Synodical Revolution, and her Motion round her own Axis from the Sun to the Sun again been performed in the ſame Time; a Spectator in the Moon would have conſtantly ſeen the ſame Side of the Earth toward him. And then, with as good Reaſon, he might have deny'd the Earth's turning round its own Axis, as any one on the Earth can now deny the Moon's having ſuch a Motion, becauſe ſhe ſtill keeps the ſame Side toward him.

To

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* As in Fig 4; where a true Repreſentation of both Paths are ſhewn.

To an Eye placed in the Sun, the Moon will appear to move round about him in like Manner as the Earth alſo does; ſave only with a progreſſive Motion ſometimes faſter and ſometimes ſlower than the Earth's. For, from the New Moon to the firſt Quarter, her progreſſive Motion is ſo much ſlower than the Earth's, that at her firſt Quarter, ſhe will have fallen behind it, a Space equal to the Radius of her Orbit, or Diſtance from the Earth. From that Time, her Motion is accelerated to her third Quarter; and then ſhe is as far before the Earth as ſhe was behind it at her firſt Quarter. And from her third Quarter to her firſt, her progreſſive Motion is again ſlower than the Earth's. So that in the Middle between theſe two, ſhe will be between the Sun and Earth, or at her Conjunction; as in the Middle between her firſt and third Quarters, the Earth will be between the Sun and her; ſhe being then at her Oppoſition or Full: As is plain by Fig. III, where the Moon travelling along the irregular Curve KLMNO, as ſhe accompanies the Earth, does as truly move round about the ſame, as, if the Earth was at reſt, ſhe would do in the Circle U W X Y. And now, for my own Part, if I was deſired to account for the regular Series of Days and Nights in the Moon; I ſhould be at a Loſs how to do it any other Way, than by ſaying that it is owing to her Motion round her own Axis; as the like is produced in the Earth by its diurnal Motion. For we can no more ſuppoſe the Sun to be carried round the Moon than round the Earth.

In diſcourſing formerly with ſome Gentlemen, I found that they imagined the Moon's progreſſive Path made Fig. 5. Knots or Loops once in every Lunation, as at A and B: in which Caſe, as ſeen from the Sun, ſhe would appear Stationary at S, Retrogade at R, and in all the reſt of her Path, Direct. This excited my Curioſity to draw a Repreſentation of her true abſolute Path; which I publiſhed in the Year of our Lord 1745; and this Delineation ſhews plainly, that ſhe can no more appear either Stationary or Retrogade, as ſeen from the Sun, than as ſeen from the Earth. For her Progreſs is every Day at leaſt 880,000 Miles more than the whole Diameter of her

Orbit; and her abſolute Motion is always Concave to the Sun, as her relative Motion is to the Earth. This I have ſhewn (as well as I could copy the principal Lines of the ſaid Delineation, which is almoſt 36 Inches long) in Fig. 4; where the broadeſt Curve Line, from N M to N M, repreſents as much of the Ecliptic as the Earth deſcribes from any particular New Moon to the next following. And the narroweſt Curve Line where bounded by the ſame Letters, repreſents the Moon's abſolute Path during that Time; which is concave to the Sun, even at the Time of New Moon. The ſmall dotted Circles ſhew the true Magnitude of the Moon's imaginary Orbit, in Proportion to the Earth's annual Path; as the ſaid Orbit is carried along with the Earth, round about the Sun. N M ſignifies New Moon, 1 Q firſt Quarter, F M Full Moon, 3 Q third Quarter. The right Lines croſſing theſe Curves, if continued inward, would all meet in the Center of the Earth's annual Path, or in the Sun. For more Satisfaction, ſee my large Scheme thereof, or the Delineation abovementioned.

The ſtrongeſt and moſt ingenious Objection that ever I heard made againſt a Body's turning round an Axis within itſelf, if in a Circular Progreſs it ſtill keeps the ſame Side toward the Center of its Orbit; and to which, I pay the greateſt Deference, is this:

The Globes E and F, with the Axis I K, alſo the Shank G, and Crank or Bar H, are all together but one continued coherent Syſtem of Matter; a Body which turns but upon one Axis, namely I K. This Body may have been cut out of a larger ſolid Piece of Matter, as ſuppoſe the Cylinder A B C D; of which the Axis was I K. And now let us ſuppoſe this Cylinder reſtor'd to its former Solidity and Coheſion of its Parts; it may ſtill turn upon its former Axis I K; and the Globes E and F will be included and incorporated in it; and will go round with the ſame Obverſion that they had before. And any Argument that can prove that the ſaid Globes now turn round any Axis different from that of the whole Cylinder, will equally prove the ſame of every Atom in the Cylinder; which would, if true, neceſſarily deſtroy its Coheſion and reduce it to Duſt. Fig. 5.

I frankly own, that it is not eaſy (as far as my ſmall Knowledge will go) to give a full Anſwer to this Objection, nor ſo good a one as it really deſerves. For to be ſure, the Globe F being a Part of the ſame Body with the Crank H, becauſe tied thereto by the material Connector G, can no more turn round G as an Axis within itſelf, than every Atom of the Bar or Crank H turns round an Axis within itſelf; as the Connector or Shank G may ſtand upon any Part of the Crank H; and by turning the Axis I K round, the Globe F will go round the Globe E, keeping ſtill the ſame Side thereto.

In the Criterion it is aſſerted, that if a Body in its circular Progreſs ſhews itſelf all round to the Center of its Orbit, it turns round an Axis within itſelf. And here, that if the different Parts of a revolving Body turn round ſeparate Axes within themſelves, the Coheſion of that Body muſt be deſtroyed thereby, and the whole Body reduced to Duſt. Now I will ſuppoſe the Bar * that hangs the Watch upon the Knob of the Hour Hand of the Clock, to be cut into the Shape of ſeveral ſmall round Plates joined together by Slips of the Bar left un-cut between them; and they will appear like ſo many Dial Plates of Watches, pinn'd one above another, to a long narrow Bar which is hung upon the Knob; and let a Pin be put through the Center of every Plate. All theſe are but one Body; and as the whole of it is moved by the Hand of the Clock, while it ſtill hangs perpendicularly, every Pin will deſcribe a Circle (whoſe Diameter will be of the ſame Length with that which the Knob on the Point of the Hour Hand deſcribes) and every Plate in one Revolution will ſhew itſelf all round to the Center of the Circle which its reſpective Pin deſcribes. And therefore, according to the Criterion, every ſingle Plate muſt in one Revolution as certainly turn round an Axis within itſelf, as if there was but one Plate hung by a Thread; and according to the Tenor of the laſt Objection, the Coheſion of the whole Body muſt be deſtroyed, and its Parts reduced to Duſt. But theſe two agree not together; for we ſee plainly, that the Body keeps its Solidity when in Motion, as well as it does when at reſt.

* Page 52.

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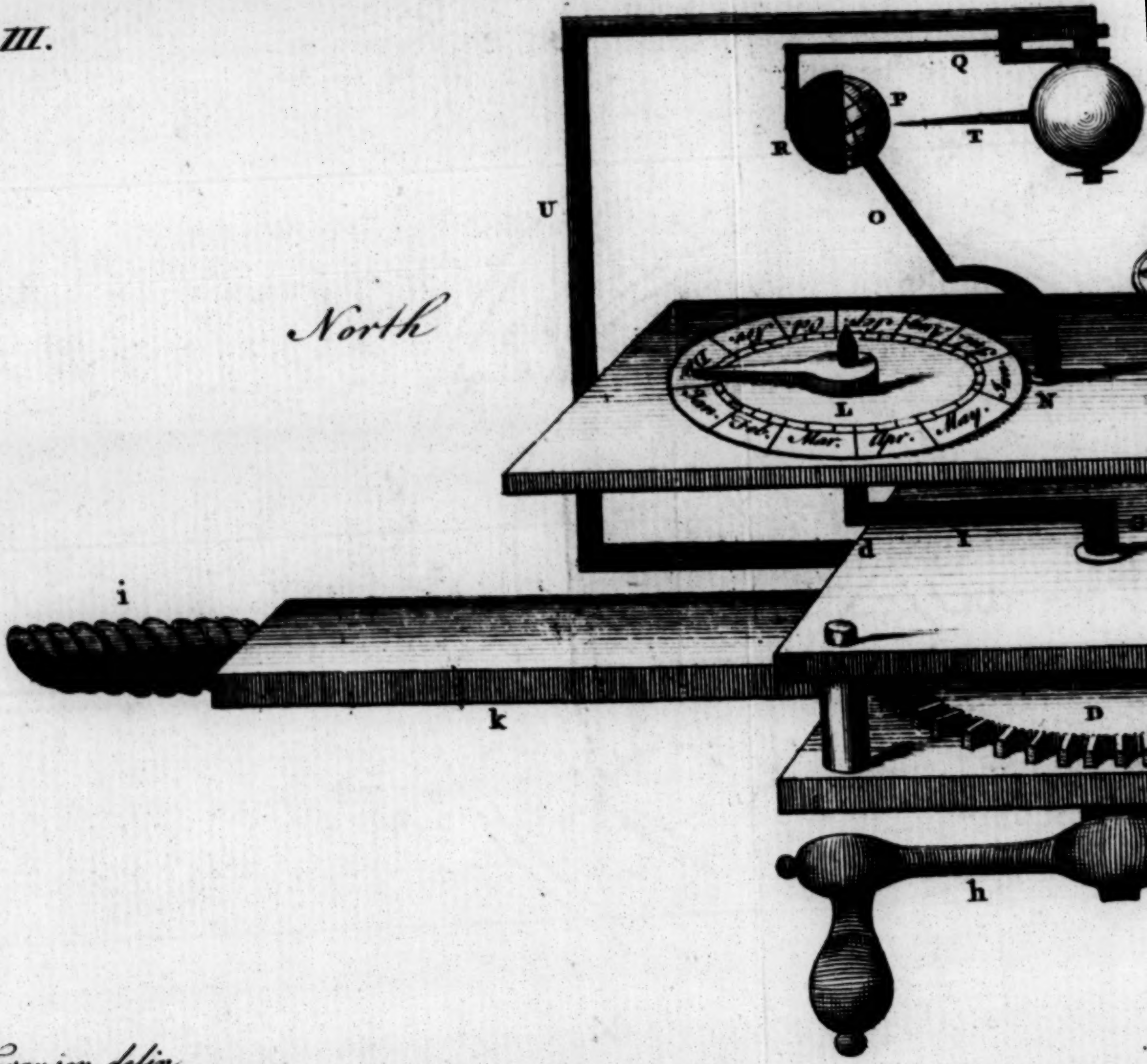
Plate III.



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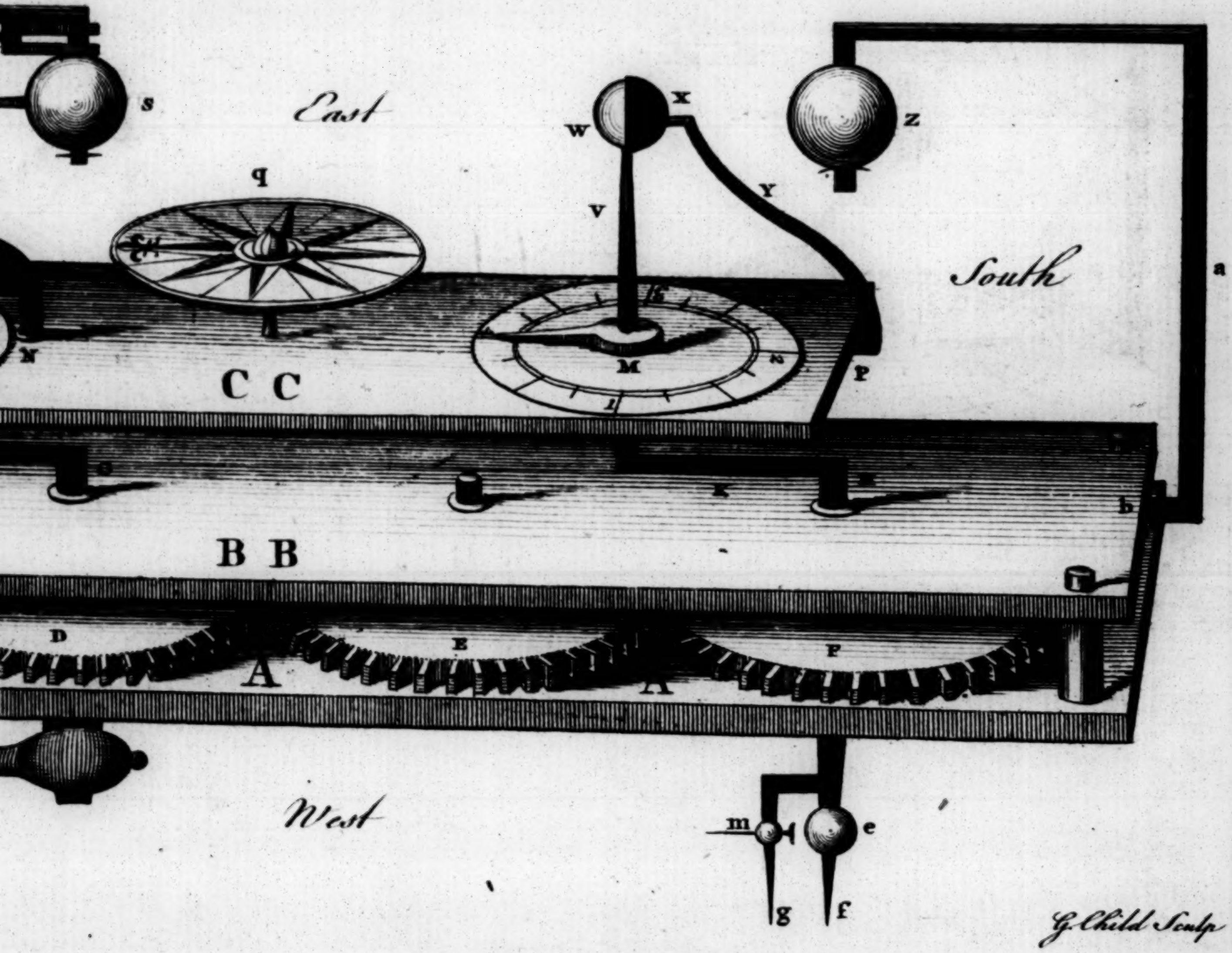

G. Child Sculp

Enough has been ſaid already againſt the Criterion; and now it remains for me to prove, that while the whole Cylinder turns round an Axis in the Middle thereof, every Atom of the Cylinder, or of the Crank H, turns round a diſtinct Axis of its own, or mathematical Line within itſelf. And to prove this, I have contrived * a Machine on purpoſe, which I ſhall deſcribe by and by.

I know nothing more abſurd, than it would be to ſay that the Seaman's Compaſs turns round an Axis within itſelf, while its North Point continues true to the Pole, or to any Degree of Variation from it. And this it will do, let the Ship turn round ever ſo often; and for every Time the Ship turns round, the Spike whereon the Compaſs hangs, turns alſo. And if an Index was fix'd on the Spike below the Compaſs, it would turn round below all the Points of the Compaſs in the Time that the Ship turns once round; without having any Power to turn the Compaſs round with it. And whoſoever pretends to prove, that the Compaſs turns round its Axis, as often as it ſhews itſelf all round to any Part of the Ship, muſt needs prove, that the fix'd Poles of the World go round through all the Degrees of a great Circle, on the Earth or in the Heavens, for every Time that the Ship turns, or is turned round by her Managers, when they pleaſe. But the Compaſs keeps parallel to the Horizon in all its Points; and therefore, the turning of the Ship can no more turn it round its Axis, than the Horizon can be turned thereby.

Thus much being premis'd, I now proceed to the Deſcription of the abovementioned Machine; in which A A and B B are two fix'd Plates, kept together by Pillars, as in the Figure. D, E, and F are three Wheels of equal Numbers of Teeth, biting into one another; ſo that if any one of them be turned, the other two turn equally round with it: D and F turning the ſame Way, and E the contrary. On the Axis of D and of F (above the Plate B B) at G and H, is fix'd the Crank I and the Crank K; whoſe perpendicular Shanks come through the Plate C C, at L and M; within which Plate, they Plate III.

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* A three wheel'd *Orrery*.

eaſily turn. The Bar k has one of its Ends fix'd into the Plate A A, and has a Screw, as i, on its other End, which being ſcrewed into a Table or Wall, will keep the Machine from ſhaking, while the moveable Parts of it are wrought by the Handle h. In the Plate B B at b, is fix'd the Wire a; having the Globe Z on its other End, hanging over the Center of the Wheel F. On the Shank V, as an Axis, is fix'd the Globe W, and the Index M; and on the other Shank, the Index L is fix'd. The crooked Wire Y has its lower End fix'd in the Plate C C, at p; and its upper End into the Cap X, within which the Ball W turns freely round. In the other End of the Plate B B, is fix'd the Wire U, at d, whereon the Globe S hangs over the Center of the Wheel G; ſo as it may freely turn round on the Wire. To the Globe S is fix'd the Piece Q, from which comes a ſmall Wire that is fix'd in the Cap R, of ſuch a Length as to allow the Cap to turn freely round the Globe P, whoſe Axis O inclines 23½ Degrees, being fix'd in the Plate C C, at N. And from the Globe S proceeds a Wire T, which always points toward the Center of the Globe P.

Having fix'd the Machine to a Table, by the Screw i; turn the Handle h, and you'll ſee all the Wheels and Cranks turning equally round with the Handle. By the Cranks, the moveable Plate C C is carried over and over the fix'd Plates, in a parallel Motion, without turning round any Axis whatſoever. For if a Seaman's Compaſs as q, be hung on this Plate, the ſame Points thereof will conſtantly look to the ſame Points of the Horizon; and will always ſtand perpendicularly over the ſame Parts of this moving Plate, which never changes its Paralleliſm from the fix'd Plates. But the Shank or Axis V turns the Index M quite round a graduated Circle, on the Plate C C, marked 1, 2, 3, 4, in every Revolution of the Handle. And at the ſame Time the Globe W, on this Axis, is carried round about Z, to which it ſtill keeps the ſame Side; but ſhews itſelf quite round to all the Points of the Horizon, and turns round within the Cap X, which ſtill faces toward one and the ſame Point thereof; becauſe it is fix'd, by the crooked Wire Y, into the Plate C C. In one Revolution, W will ſee Z all round; becauſe

cauſe Z turns not. But if the Cap X be taken away, and theſe Globes connected by a Wire, they will turn equally round their Axes, and will conſtantly keep the ſame Sides to one another: In which Caſe, either viewed from the other, would appear to be at reſt on its own Axe. But viewed by an Eye at reſt, and at a Diſtance from them both, they turn equally round their Axes.

Now, as the Index M and the Globe W are both fix'd on the Shank or Axis V, they muſt turn equally with it. And, as in every Revolution of the Handle, they both ſhew themſelves round to all the fix'd Points of the Horizon; the Index turning round a Circle which keeps parallel thereto, and the Globe turning round within a Cap which ſtill looks towards one Point thereof; it is plain that both the Globe W and Index Y do each turn round an Axis or mathematical Line within itſelf; as the Shank V neceſſarily does. And this Shank might be fix'd on any Place of the Crank K (provided the other Shank was fix'd on the like Place of its Crank, without which the Machine would not perform) for it would ſtill turn the Index and Globe round, the ſame Way as it now does by being fix'd to the End thereof, whereon it ſtands. Therefore, while the whole Crank is carried round the Axis H of the Wheel F, every Atom of the Crank muſt turn round an Axis or mathematical Line within itſelf; and the whole being carried round through different Points of Space, in the Time that every Part or Atom turns round its own Axis, their Coheſion cannot be deſtroyed, nor the Crank reduced to Duſt.

The Moon's Orb ſubtends ſo ſmall an Angle as ſeen from the Sun, that it ſcarce exceeds $\frac{1}{3}$ of a Degree. And in a Lunation ſhe moves through ſuch a large Space in accompanying the Earth, as in round Numbers amounts to 41,130,000 Miles; which is 40,650,000 Miles more than the Diameter of her Orbit. Therefore, 5 Degrees Inclination of ſo ſmall an Orbit, will make no viſible Difference of the Moon's Path, from what it would be if her Orbit lay in the Plane of the Ecliptic. Conſequently, a very near Reſemblance of the Moon's abſolute Path may be delineated by the Machine, in the following Manner.

On

To draw a Repreſentation of the Moon's true Path in the Heavens.

On the Middle of a ſmooth wooden Floor, of a Room that is at leaſt 14 Feet wide, fix a Wheel with a Groove round its Edge of 24$\frac{76}{100}$ Inches Diameter; and fix an upright Pin in the Center of the Wheel. Then take away the Bar k from the Machine, and in its Place fix another Bar about 6$\frac{1}{2}$ Feet long; which done, meaſure 81 Inches, from the Center of the Wheel F, along this Bar; and where the Reckoning ends, make a Hole in the Bar, ſo as it may be turned freely without ſhaking round the ſaid Pin, when put thereon. Take off the Handle h; and in its Place, on the Axis of the Wheel D, fix a Wheel with a Groove round its Edge of 2 Inches Diameter; which will bear the ſame Proportion to the other groov'd Wheel, as one Lunation does to 12 Lunations and 11 Days over. On the Axis of the Wheel F, below the Plate A A, fix the Piece e m g f; in which, let e repreſent the Earth, and m the Moon: The Point g, of the Pin that paſſes through m, being $\frac{24}{100}$ Parts of an Inch from the Point f, of the Pin that paſſes through e the Earth. And this will repreſent the Moon's true Diſtance from the Earth, in proportion to the Earth's Diſtance from the Sun, which is ſuppoſed to be in the Hole of the long Bar, 81 Inches from the Earth. For as 81 Inches is to 81,000,000 of Miles, the Earth's Diſtance from the Sun; ſo is $\frac{24}{100}$ Parts of an Inch to 240,000 Miles, the Moon's Diſtance from the Earth.

Things being thus prepar'd, put the Hole in the Bar on the ſaid upright Pin; and put a Cat-gut String round the two groov'd Wheels, croſſing between them. Then turn the whole Machine round this Pin as a new Axis; making the Points f and g touch the Floor, which ſhould be covered with Paper all the Way round, over which theſe Points go; and f will deſcribe the Line of the Earth's annual Path, as g will deſcribe the abſolute Path of the Moon, while ſhe goes 12$\frac{1}{3}$ Times round the Earth from the Sun to the Sun again, in the Time that the Earth goes once round about the Sun. And ſo, you'll ſee in that Time, 12 Lunations and about 11 Days produced; ſuppoſing the Earth's Orb divided into 365 equal Parts, and conſidered as a Circle: Which does better in ſuch an Experiment, than if it were an Ellipſis;

becauſe though the Earth does move in an Ellipſis, it is in one whoſe Excentricity is ſo ſmall, as to be but a $\frac{17}{1000}$th Part of the Radius of its Orbit; which is too ſmall to make any ſenſible Alteration to the Eye, even in this large Scheme; wherein the Moon's Excentricity would ſtill be leſs viſible.

In carrying this Machine round a Sun, which may be ſtuck upon the Top of the fix'd Pin that comes through the long Bar, the Cat-gut turns the Wheels round, and ſerves inſtead of a Handle for that Purpoſe. And if the Earth's Orbit be divided into 365 equal Parts or Days, you'll ſee, that while this little Earth e goes through $29\frac{1}{2}$ of them, the Moon m will go round it, from the Sun to the Sun again; ſtill keeping the ſame Side toward the Earth, as is ſhewn by a ſmall Pin put through one of her equatoreal Diameters. And in every Lunation, the ſaid Pin will turn quite round the Path of the Moon's Axis, making all poſſible Angles therewith; croſſing it at right Angles at New and Full Moon, and lying juſt over it at the Quadratures. *An ocular Demonſtration of the Moon's turning round her own Axis.*

Moon's Phaſes, &c.

Carrying the Machine round in this Manner, you have a true Repreſentation of the Moon's Phaſes in every Lunation, by the Moon W, as ſhe turns round within her Cap X, while ſhe goes round the Earth Z from the Sun to the Sun again; and likewiſe, the Difference between her periodical and ſynodical Revolution; agreeably demonſtrated to the Sight.

Take away the little Earth and Moon, with the long Bar and groov'd Wheels; fix the ſhort Bar k in its former Place; then ſcrew it to the Table, and put on the Handle, as in the former Experiments *.

Take off the Globes Z and W, with the Cap X; leaving only the Globe S to repreſent the Sun, and the Globe P to repreſent the Earth on its inclining Axis O, and half covered by the Cap R. A Sketch of a Map, with the Equator, Tropics, Polar Circles, and 24 Meridians, may be delineated on this *Terrella* or little Earth.

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* Page 66.

A Repreſentation of the four Seaſons.

The Machine being put in this Order, it will ſhew all the Phænomena of the different Seaſons, with the different Lengths of Days and Nights, throughout the whole Year. For, as the Handle is turned round, the Earth is carried round about the Sun, in the Time that the Index L goes round the Circle of Months. The Earth's inclined Axis keeps always parallel to itſelf, as in the four Wheel'd Orrery already deſcribed. And the Solar Ray T conſtantly points from the Sun toward the Earth's Centre; and conſequently, in the Earth's annual Revolution, it will deſcribe the Spirals of the Sun's Declination from Tropic to Tropic; ſhewing every Day over what Places he ſhines vertically at Noon. The Edge of the Cap repreſents the Circle bounding Light and Darkneſs; for it always faces the Sun, ſhewing when he riſes and ſets to the Poles alternately, as the Index L ſhews it to be in *March* or *September*. The Hours are marked on the Equator, where the Meridians croſs it; and therefore, although the Earth turns not round its Axis by the Motion of the Machinery, yet at any Time of the Year, as ſhewn by the annual Index L, the Earth may be turned round its Axis by Hand: And conſequently, the Time of Sun riſing and ſetting ſhewn at any Place, on any given Day in the Year; by obſerving how many Meridians or Hour Circles cut the Parallel of Latitude of the given Place without the Cap, or how many Hours it takes, as ſhewn on the Equator, from the Time that any particular Meridian Semi-circle comes out from below the Cap, until it goes in under the ſame, by turning the Earth round its Axis.

Here, the Motion of the Earth being the very ſame as in the four Wheel'd Orrery, the ſame Things belonging to the Earth may be ſhewn in this Machine as in the other; which being already deſcribed *, I need not repeat the Deſcription in this Place.

A few Wheels, by a multiplied Motion, from the Axis of the Index L to the Earth's Axis, would give the Earth its diurnal Motion; which any ſkilful Mechanic might eaſily contrive. Hence, becauſe in this Manner, the Earth might be made to turn 365 Times round its own Axis, in the Time that it goes round the Sun; and

* Page 23, 24, & 25.

and has ſuch a Motion begun and carried on, by a Wheel fix'd on the ſame Axis with the Index L; it is a plain Proof that the ſaid Wheel turns round its own Axis; the other Wheels not being carried round about it, as they muſt needs have been, to have turned round their Axes by Means of a dead Wheel. And yet this Axis is no more than the Shank of the Crank I; as the Axis of the Index M, and Moon W, is of the Crank K; the one turning equally round with the other.

The Ball or Earth P has no Motion round its Axis O, as has been taken Notice of already, that Axis being fix'd into the Plate C C; for which very Reaſon, P ſhews itſelf all round to S, in the Time that it goes round the ſame. To illuſtrate this a little further, I ſhall only give one Example, and ſo conclude.

Let us ſuppoſe any Number of Planes interſecting one another in the Center of the Moon's Orbit, to paſs through the Periphery of the ſame, and to extend ſo far, as to paſs through all the fixed Stars in the Ecliptic that are in their Way. Theſe Planes, by keeping the ſame Signs and Degrees of the Moon's Orbit toward the like Signs and Degrees of the Ecliptic, will connect them ſo together, that the Moon's Orbit can no more turn round an Axis within itſelf than the Ecliptic does. And yet in every different Degree of the Earth's annual Revolution, a different Degree of the Moon's Orbit will point toward the Sun (which occaſions the Difference between the Moon's Periodical and Synodical Revolution). And conſequently, in a Year, the Moon's Orbit will ſhew itſelf all round to the Sun; and really does ſo, without ever changing its Signs from thoſe of the Ecliptic; although her Nodes go backward through all her Signs in 19 Years, and her Apogee goes forward through them all in 9; without any ſuch interſecting Planes as here ſuppoſed.

I allow that concerning this Example, a Difficulty may very naturally ariſe in the Minds of thoſe who are unacquainted with Aſtronomy; after hearing, that the Center of the Moon's Orbit is carried round about the Sun, in the Periphery of the Earth's annual Orb, whoſe Diameter is 162 Millions of Miles long. Becauſe they will

think

think thus: Suppoſe a remarkable Star was fix'd in the Heavens, at the Beginning of every Sign of the Ecliptic, and of the Moon's Orbit; the ſaid Planes would only paſs through the Stars of the one and of the other, if the Moon's Orbit was at reſt in the Center of the Ecliptic. But, as that is not the Caſe, how can Planes that are fix'd in the Moon's Orbit, and in the Ecliptic, keep their reſpective Places in both, without changing*; as the Moon's Orbit continually moves, and the Ecliptic is at reſt? To clear up this, I anſwer, that the Diameter of the Earth's annual Orbit is but a Point when compared to its immenſe Diſtance from the fix'd Stars; ſubtending no Angle as ſeen from any one of them. And therefore, it makes no Difference, whether a Body, that is ſeen by an Eye at the Diſtance of the Stars, is fix'd in the Center of the Earth's Orbit, or whether it moves along the Circumference of the ſame; ſince, if right Lines were drawn from all the Points of the Earth's annual Orbit, to an Eye ſo placed, all thoſe Lines would be phyſically parallel to each other.

* Page 51. l. 5, 6, & 7.

FINIS.

ERRATA.

Page 21, Line 17, *for* Axis *read* Axes. P. 55, L. 2, *for* al *read* all. P. 59, L. 2, *for* Axis *read* Axes. P. 63, in the laſt Line, *for* Cohe ſin *read* Coheſion.